Marine Fisheries
REVIEW
Vol. 62, No. 1
2000
United States Department of Commerce

Menhaden

Marine Fisheries REVIEW

W. L. Hobart, Editor
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On the cover:
Menhaden from the day's catch. Photograph by Joseph W. Smith stylized via a crosshatch brushstroke filter.

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The *Marine Fisheries Review* (ISSN 0090-1830) is published quarterly by the Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., BIN C15700, Seattle, WA 98115. Annual subscriptions are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402: The annual subscription price is $16.00 domestic, $20.00 foreign. For new subscriptions write: New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

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This publication is available online at http://spo.nwr.noaa.gov/mcontent.htm

The Ancillary Harvest of Atlantic Menhaden, *Brevoortia tyrannus*, Roe on the North Carolina Coast

JOSEPH W. SMITH and DEAN W. AHRENHOLZ

Introduction

Extraction of fish roe for food is a common practice worldwide and includes a diverse array of fish families. Historically, roe from sturgeon (Acipenseridae) has long been processed into caviar and is often referred to as "black gold," since it may be one of the highest priced fisheries products in the world (Iversen, 1990). As worldwide demand for fish roe has increased in recent years (Iversen, 1990), roe products have been developed and prepared from such diverse species groups as the lumpfish (Cyclopteridae) in the North Atlantic (Stevenson and Baird, 1988), flyingfishes (Exocoetidae) in the tropics, capelin (Osmeridae) in more boreal waters (Iversen, 1990), and striped mullet (Mugilidae) along the southeastern United States (Leard et al., 1995).

In U.S. coastal waters, herrings of the family Clupeidae are among the most sought-after fishes for their roe. By far, the most lucrative herring roe fisheries occur in Alaska for the Pacific herring, *Clupea harengus pallasi*, with smaller quantities of Atlantic herring, *Clupea harengus harengus*, harvested for the roe trade off New England; most processed roe from these fisheries is exported to Japan (Herrfurth, 1986). Along the U.S. southeastern coast, several anadromous, alosine clupeids, namely, the blueback herring, *Alosa aestivalis*; the hickory shad, *A. mediocris*; and the American shad, *A. sapidissima*, are highly esteemed for their flesh and roe, and are targeted by traditional riverine and inshore fisheries (Smith, 1907; Manooch, 1984).

On a coastal basis, the migratory, estuarine-dependent Atlantic menhaden, *Brevoortia tyrannus*, is probably the most abundant clupeid on the U.S. Eastern Seaboard. Atlantic menhaden form large, nearshore surface schools from spring through December, and are the targets of a large, industrial purse-seine fishery for fish meal, fish oil, and fish solubles (Smith, 1991). Between 1995 and 1999, annual landings for reduction have averaged about 260,000 t yr^{-1}, although participation in the fishery by 1999 had dwindled to two factories and about 15 vessels, down from five factories and about 35 vessels in 1990. Historical estimates of maximum sustainable yield from the fishery range from 370,000 to 470,000 t yr^{-1} (ASMFC, 1999).

During fall and winter Atlantic menhaden migrate south around the North Carolina capes, and support a temporal segment of the purse-seine fishery called the Fall Fishery (Smith et al., 1987; Smith, 1999). Schools of roe-bearing fish are often harvested by purse-seine vessels from the Carteret County port of Beaufort, North Carolina, and are landed at a local reduction factory. At various points in the harvest and processing operations, small amounts of menhaden roe are manually extracted from whole fish for local consumption, and the carcasses are returned to the reduction process-

The authors are with the National Marine Fisheries Service, NOAA Center for Coastal Fisheries and Habitat Research, 101 Pivers Island Road, Beaufort, North Carolina 28516. Mention of trade names or commercial firms in this paper does not imply endorsement by the National Marine Fisheries Service, NOAA. Corresponding author is J. W. Smith, (252) 728-8765, 728-8784 [Fax], email:joseph.w.smith@noaa.gov

ABSTRACT—Gravid Atlantic menhaden, Brevoortia tyrannus, *are available along the central coast of North Carolina during the fall and are harvested by the purse-seine fleet from the port of Beaufort. Virtually all of the catch, sexually immature fish included, is reduced to fish meal, fish oil, and fish solubles; however, minor quantities of roe from ripening female menhaden are extracted for local consumption. Routine and selective port sampling information was used to characterize the seasonal and biostatistical nature of the roe menhaden catches at Beaufort. Fishermen recognize two size classes of roe Atlantic menhaden: "forerunners," which are usually the smallest and earliest adult menhaden encountered in the Fall Fishery, and "mammy shad," which are the largest menhaden harvested and produce the greatest roe yields. Roe is extracted from female fish at various points along the reduction process stream and by several techniques. Vessel crewmen and factory personnel extract menhaden roe for personal and local consumption. Undetermined quantities of menhaden roe are channeled into local retail seafood markets. Wholesale prices are about $20 per gallon of roe, while retail prices are about $5 per pound. Carteret County, North Carolina, is probably the only area on the U.S. Atlantic and Gulf coasts where menhaden roe is sold in retail seafood markets. The potential of extracting menhaden roe for foreign markets is discussed.*

[1] W. B. O'Bier and E. J. Levi, Menhaden Program, NMFS, NOAA Center for Coastal Fisheries and Habitat Research, Personal commun.

ing stream. Although crew members of menhaden vessels from Reedville, Va., and numerous ports in Louisiana and Mississippi extract small quantities of roe for home consumption[1], the practice appears unique and endemic to the area surrounding the port of Beaufort to the extent that minor quantities of menhaden roe enter local retail seafood markets. In this paper we describe 1) the seasonality and availability of roe Atlantic menhaden in the vicinity of the port of Beaufort, North Carolina, 2) the biological characteristics of the roe fish harvested, and 3) the roe extraction techniques and disposition.

Observations

Seasonality and Availability of Roe Menhaden Along the North Carolina Coast

Atlantic menhaden stratify by size and age along the U.S. east coast during summer, with the oldest and largest fish migrating as far north as the Gulf of Maine (Nicholson, 1972). Although spawning occurs during every month of the year (Judy and Lewis, 1983; Ahrenholz, 1991), spawning intensity is thought to increase as adults move south along the Mid Atlantic U.S. coast during October and November, peaks off the North Carolina coast in winter, and continues at lower levels as adults move north again in spring (Ahrenholz, 1991). Most Atlantic menhaden attain sexual maturity as late age-2 fish just prior to turning age-3 (Higham and Nicholson, 1964; Lewis et al., 1987).

All age classes of Atlantic menhaden in the coastal population from age-0 to 5+ may be available during the Fall Fishery, although catches and fishing effort are highly weather-dependent (Smith et al., 1987). Two size classes of ripening adult fish are recognized by menhaden fishermen in the Beaufort area (Fig. 1). "Forerunners," so called because they are usually the first spawners encountered in the Fall Fishery (Frye, 1978), are the smallest and youngest fish of the two groups. We suspect that the earliest "forerunners" to appear off the North Carolina coast may be local fish which have recently attained sexually maturity. Their roe sacs are relatively small, and fishermen sometimes forego opportunities to extract roe from "forerunners" because of low roe yields. "Mammy shad" are the largest and oldest class of spawners occurring in the Fall Fishery. Catches of "mammy shad" are much anticipated because of their relatively high roe yields.

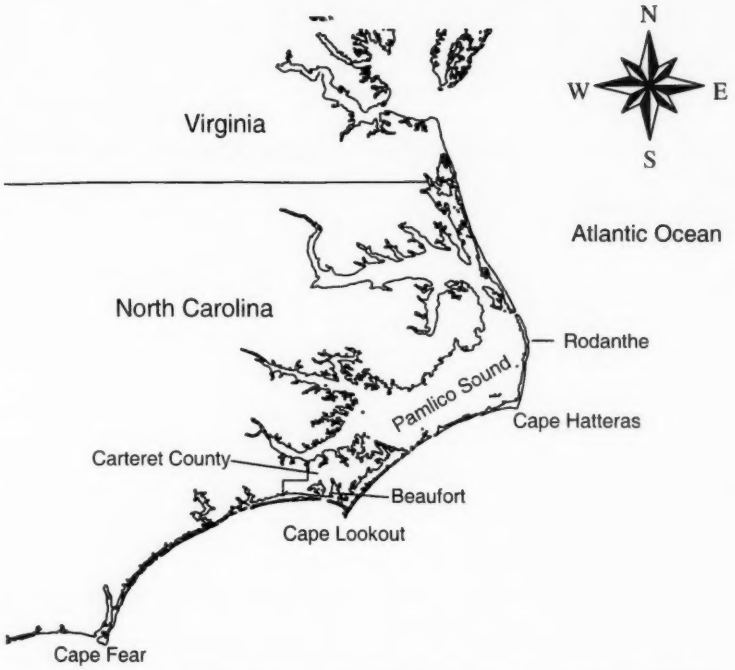

Figure 1.—Coastal North Carolina, showing the North Carolina capes and Carteret County.

A review of port sampling records at Beaufort for recent years (since 1988) revealed information on the frequency of landings of roe menhaden at Beaufort (Fig. 2). Initial catches of roe fish off the North Carolina coast occurred as early as 12 October 1989, but most frequently occurred in early to mid-November. Early runs of roe fish are usually of the "forerunner" class, which may be encountered by vessels from Beaufort as far north as Rodanthe near Cape Hatteras (Fig. 1). Initial catches of "mammy shad" most often occur south of Cape Hatteras during mid- to late December. Peak catches are made between Christmas and New Year's near Cape Lookout, with final catches of roe fish made farther south toward Cape Fear in early January.

Biological Characteristics of Roe Menhaden

Size and age frequency distributions of adult Atlantic menhaden were acquired through routine port sampling efforts (Smith, 1991), and selected sampling efforts directed at catches with ripening fish during fall 1988 and 1989. Specimens were sexed, measured for fork length (FL), weighed to the nearest gram, and a scale patch was removed for ageing (June and Roithmayr, 1960). Ripe ovaries were removed and weighed to the nearest gram. Gonadosomatic indices (GSI) were calculated [(gonad weight/body weight) × 100] to express gonad weight of females as a percent of body weight. To verify that gonads were in a ripening stage, a small portion of selected gonads were preserved in 10% buffered formalin solution, sectioned by standard histological techniques, then examined under a compound microscope.

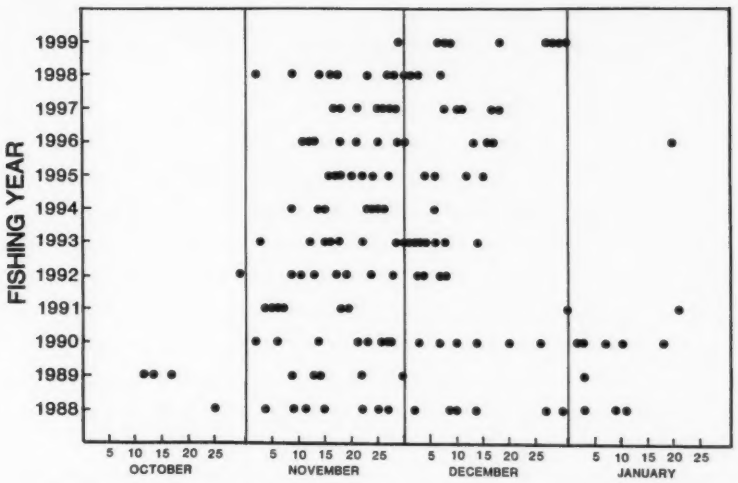

Figure 2.—A scatter plot of dates when roe menhaden were landed at Beaufort, North Carolina, 1988–1999 ("Fishing year" includes January of the following calendar year).

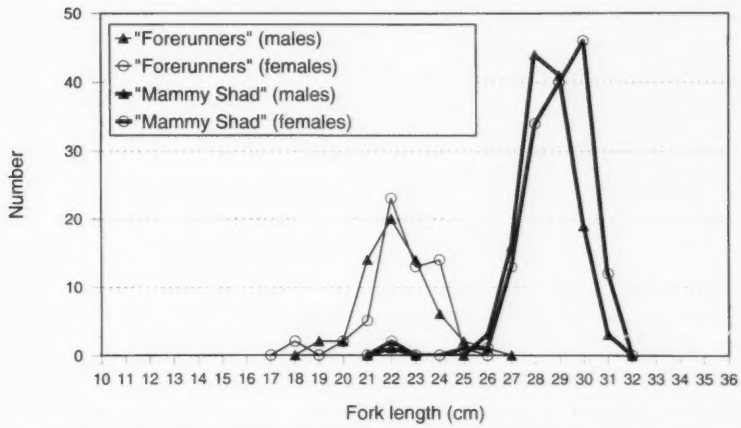

Figure 3.—Fork length frequency histogram (cm FL) of male and female "forerunners" and "mammy shad" (roe Atlantic menhaden) landed at Beaufort, N.C., in 1989 and 1988, respectively.

Males in the "forerunner" class of Atlantic menhaden from samples in November 1989 ranged from 19 to 26 cm FL and 120 to 309 g; females ranged from 18 to 25 cm FL and 97 to 294 g (Fig. 3, Table 1). Overall age composition (sexes combined, $n = 63$) was 79% age-2 fish and 21% age-3 fish (Fig. 4). Mean weight of ovaries in the "forerunner" sample was 14.2 g, and mean GSI was 6.4%.

The "mammy shad" class of Atlantic menhaden sampled in December 1988 was larger than "forerunners" in all morphometric categories (Table 1), as well as being older (Fig. 4). Males in the "mammy shad" class of Atlantic menhaden ranged from 22 to 31 cm FL and 164 to 567 g; females ranged over the same FL interval and weighed from 169 to 608 g (Fig. 3). Overall age composition ($n = 274$) was 3% age-2, 41% age-3, 36% age-4, 20% age-5, and 1% age-6 fish (Fig. 4). Mean weight of ovaries in the "mammy shad" sample was 26.9 g, and mean GSI was 6.2%. A simple scatter plot of ovary weight on FL (Fig. 5) showed two distinct clusters of resultant points.

Table 1.—Statistical information (FL, body weight, ovary weight, and gonadosomatic indexes) for female "forerunner" and "mammy shad" Atlantic menhaden landed at Beaufort, N.C., in 1989 and 1988, respectively.

Variable	Mean	S. D.	Min.	Max.
"Forerunners" (n=59)				
Fork length (mm)	224	13.3	178	245
Weight (g)	217	40.9	97	294
Ovarian weight (g)	14.2	6.5	1	30
GSI	6.4	2.5	1	11.6
"Mammy shad" (n=149)				
Fork length (mm)	289	14.4	216	313
Weight (g)	425	64.3	169	608
Ovarian weight (g)	26.9	10.8	1.4	65.4
GSI	6.2	2.0	0.3	12.1

Roe Extraction and Disposition

The colloquial phrase in coastal North Carolina for removing roe from gravid menhaden is "breaking roe." Literally with the ventral surface of the fish held outwards, a fisherman grasps a menhaden by the head with one hand and the caudal peduncle with the other hand, and "breaks" the fish nearly in half opening the visceral cavity in a ventral to dorsal direction beginning near the vent (Fig. 6, 7). "Roe breakers" usually wear gloves as the menhaden's ventral scutes are sharp and cutting. In another and less-strenuous technique, the blade of a pocket knife is inserted into the vent and a long incision is made along one flank of the body cavity. With the viscera exposed, the yellow to yellow-orange colored ovaries are readily apparent. They are physically pulled from the body cavity and dropped into a nearby container. If the fish are fresh and well chilled, the ovarian membrane remains intact and is free of most other visceral parts. Externally, male and female menhaden are indistinguishable except for size. Fisherman tend to be selective, choosing the largest and most rotund specimens as having a high probability of being females with large roe sacs. Males are generally sleeker and less rotund in body shape. Ripe testes of males are called "white roe," and are returned to the reduction process stream.

Crew members and plant personnel break roe for personal consumption, while undetermined quantities are chan-

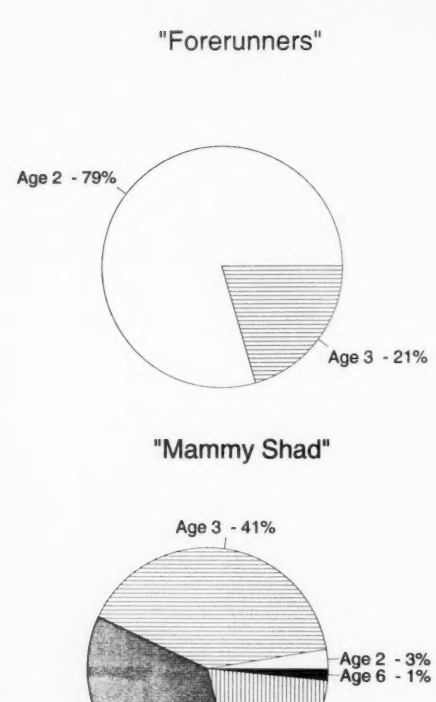

Figure 4.—Age composition "forerunners" and "mammy shad" (roe Atlantic menhaden, sexes combined) landed at Beaufort, N.C., in 1989 and 1988, respectively.

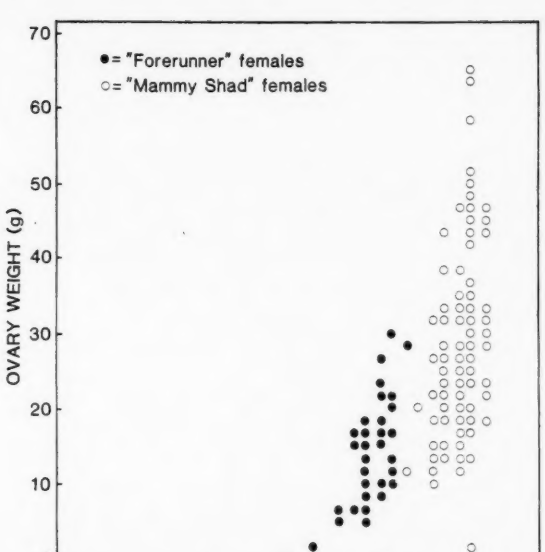

Figure 5.—Scatter plot of ovary weight (g) on fork length (cm) for "forerunners" and "mammy shad" Atlantic menhaden landed at Beaufort, North Carolina.

neled into local retail seafood markets. Several vantage points in the harvest and reduction operations provide access to the roe menhaden. Vessel crewmen get initial opportunities to "break" roe fish on top of the fish hold in between purse-seine sets on the fishing grounds or while returning to port. Carcasses are simply returned to the fish hold. Factory personnel and a few local watermen gain access to roe menhaden as the fish are unloaded into the fish plant. As a vessel's fish holds are partially flooded, fish and water are pumped to the factory. The fish pass across de-watering screens, are counted volumetrically, and then are shunted into one of two holding bins or "raw boxes" prior to being steam cooked. The fish are transported to the raw boxes by a series of conveyors or "drag lines," which supply continuous lines of fish to the "roe breakers" at several opportunistic vantage points. Carcasses are conveniently returned to the drag lines. The final chance to extract roe comes in the raw box only if the cooking operation has not commenced. Fish tumble into the raw box from an overhead drag line and pile on the raw box floor. "Roe breakers" don rain gear and boots, enter the raw box, and break roe near the base of the ever-increasing mound of fish (Fig. 8).

The container of choice for collecting menhaden roe is a plastic 5-gallon bucket. Depending on the size of the fish, efficient "roe breakers" may fill the bucket in a few hours. "Wholesale" purchases of roe are usually volumetric and by the gallon in a plastic jug or jar, although one-half gallon and quart amounts are occasionally sold in sealtight plastic bags. Through the 1980's and 1990's "wholesale" purchase price of roe was fairly stable at about $20 per gallon. Roe from initial catches of gravid fish in November, or during fishing years when roe fish are scarce, often commands a higher price of $25 per gallon. On the other hand, when roe fish are abundant the price may fall to $18 per gallon. At local retail seafood stores menhaden roe is known as "shad roe," and prices average about $5 per pound. One well established restaurant in the area often advertises "shad roe" on its marquee in December. Local aficionados of menhaden roe usually prepare individual roe sacs for table fare by breading them in cornmeal followed by deep-fat frying. Fried roe is served as a meal with several vegetables, and is especially popular during the Christmas Holidays among long-time Carteret County residents.

Discussion

Most roe products are exceptionally valuable relative to the given species'

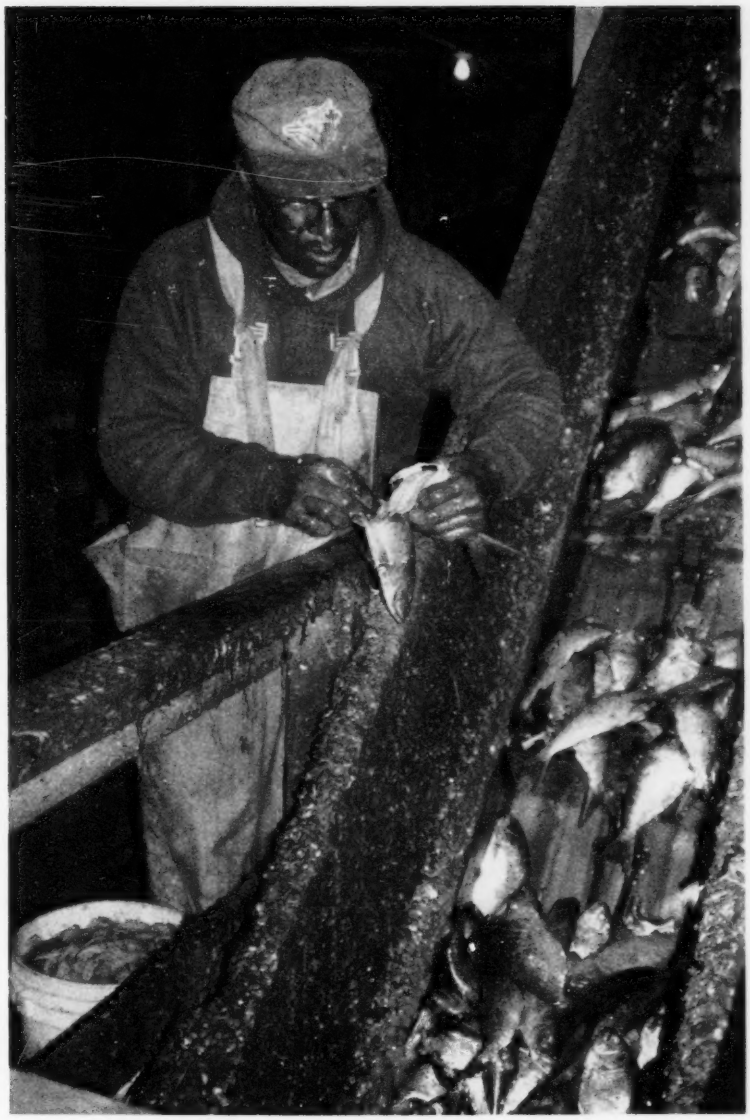

Figure 6.—Factory employee "breaks" a roe Atlantic menhaden at Beaufort Fisheries, Inc., in Beaufort, North Carolina. Note exposed roe sacs of "broken" fish, drag line of fish moving upward, and five gallon bucket of menhaden roe at bottom and left.

flesh. For example, landings of lumpfish roe in Newfoundland climbed to over 3,000 t in 1987; however, Stevenson and Baird (1988) reported negligible landings of lumpfish carcasses; lumpfish flesh is not highly regarded table fare, and with high water content and low protein and oil yields, it is unsuitable for reduction. Thus, Newfoundland fishermen tend to cull lumpfish carcasses at sea (Stevenson and Baird, 1988). "In the round" catches of striped mullet, *Mugil cephalus*, along the southeastern U.S. coast have traditionally been marketed for local consumption (Leard et al., 1995). In recent decades, directed and lucrative fisheries for roe mullet have developed during fall and early winter. Most processed mullet roe is exported to Asian markets, while carcasses from the roe fishery are usually in such poor condition that they are sold for bait (Degner et al., 1989, cited in Leard et al., 1995). In the

northeast Pacific during the late 1980's, the practice of "roe stripping" in the Alaska pollock, *Theragra chalcogramma*, fishery, that is, extracting roe and discarding female carcasses and males in the round, was scrutinized for its wastefulness of edible fish protein (Alverson, 1990).

Could an export market for menhaden roe develop, as did Asian markets for striped mullet roe that developed in the U.S. southeast in the 1980's? The answer is probably "no" for two reasons. First, the roe menhaden season along the central North Carolina coast is relatively short at only about two months. Moreover, availability of adult menhaden is highly variable, as is the winter weather off the North Carolina capes. Reliable and marketable quantities of menhaden roe would be difficult to guarantee to foreign concerns. Second, the menhaden reduction plants are generally not constructed to handle food-grade processed products. Roe processed for human consumption would obviously require more stringent handling criteria than currently exist at menhaden reduction facilities. Thus, consumption of menhaden roe will probably remain endemic to a few coastal communities where roe menhaden are harvested for reduction. Moreover, judging from the litany of closures of Atlantic menhaden reduction factories in recent decades (Smith et al., 1987; Smith, 1991; ASMFC, 1999), the practice of "breaking roe" may become a ritual of the past in the not too distant future.

Figure 7.—"Broken" Atlantic menhaden (28 cm [upper] and 30 cm [lower] FL) with respective roe sacs.

Acknowledgments

We would like to thank several coworkers at the NOAA Center for Coastal Fisheries and Habitat Research for helping us process samples of roe menhaden, namely, Ron Clayton, Donnie Dudley, Sheryan Epperly, Jim Guthrie, Ethel Hall, Robert Lewis, Neil McNeill, and Patricia Raves. At the same facility, Curtis Lewis prepared most of our figures for publication, and James Waters, Charles Manooch, and Patti Marraro reviewed initial drafts of the manuscript. Bill Roumillat of the South Carolina Department of Natural Resources in Charleston graciously prepared histological sections of preserved menhaden gonads. Jule Wheatley of Beaufort Fisheries, Inc., allowed us unrestricted access to menhaden landed at his factory.

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Figure 8.—"Breaking roe" of Atlantic menhaden in the "raw box" at Beaufort Fisheries, Inc., in Beaufort, North Carolina, before the cooking process begins.

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Recreational Fisheries in Biscayne National Park, Florida, 1976–1991

DOUGLAS E. HARPER, JAMES A. BOHNSACK, and BRIAN R. LOCKWOOD

ABSTRACT—Recreational creel survey data from 28,923 intercepts collected from Biscayne National Park, Florida and surrounding waters were analyzed for January 1976 through July 1991, prior to disruptions caused by Hurricane Andrew in 1992. A total of 261,268 fish and shellfish representing 170 species or higher taxa were recorded. The average trip landed 9.03 fish and/or shellfish. Mean annual landings per angler were 4.77 fish/angler/trip (from 3.80 in 1991 to 5.83 in 1981) and dropped significantly for each of the 2 years following Florida's adoption of multiple new minimum size limits in 1985 and 1990. The relative contribution to total numerical landings by recreational party type were: skilled anglers (34.0%), food (19.8%), family (14.5%), novice (11.5%), spearfishing (10.3%), lobstering (9.6%), and other (0.3%). Five species or higher taxa accounted for more than 50% of total landings by number: white grunt, Haemulon plumieri, *15.8%; spiny lobster,* Panulirus argus, *10.6%; gray snapper,* Lutjanus griseus, *10.6%; unidentified grunts,* Haemulon *spp., 7.3%; and dolphin,* Coryphaena hippurus, *6.6%. An average of 4.39 fish or shellfish were reported released per trip. Five taxa accounted for 67% of all releases. Lobster divers reported the highest average release rate (5.73 per trip) and spearfishing the lowest (0.70 per trip). The ratio of releases to landings was 0.49:1 for all taxa, but ranged from 0.03:1 for dolphin to 1.19:1 for unidentified grunts. Spearfishing accounted for 12.0% of the total fishing trips sampled but only 10.3% of the total number organisms landed and 7.6% of all organisms caught. Hogfish,* Lachnolaimus maximus, *accounted for 49% of total spearfishing landings (13,286 of 27,015) and 84.3% of total 15,762 hogfish landed.*

Introduction

Biscayne National Park (BNP) is located in southeastern Florida just south of Miami (Fig. 1). It has a variety of subtropical marine habitats, including the most northerly coral reefs of the continental United States (Hoffmeister, 1974; Jaap, 1984). Since 1976, recreational creel surveys of anglers were conducted for BNP and surrounding waters. Survey objectives were to establish and maintain baseline recreational fisheries information for long-term resource monitoring, provide estimates of recreational harvest and fishing effort, and detect changes in harvest composition and fishery trends.

In previous studies, Tilmant et al. (1979) did not detect significant ecological impacts from anchoring or fishing activities while conducting fishery-independent underwater monitoring of the resources at selected coral patch reefs in BNP. Tilmant (1981) found no evidence of long-term declines in catch rates of frequently harvested species between 1976 and 1979, but he noted that catches of groupers (*Epinephelus* and *Mycteroperca* spp.) had declined during 1979. Tilmant (1981) concluded that size classes of harvested fishes had remained stable and that the levels of recreational consumption between 1976 and 1979 were not depleting BNP resources. Tilmant and Stone[1] estimated average annual recreational landings between 1979 and 1983 at 145,300 finfishes, 2,350 lobsters, and 450 conchs. They concluded that the percentage of sportfishing trips with landings had remained fairly stable at about 88% between 1976 and 1983.

This paper reviews available BNP recreational creel census data collected before 1992 when hurricane Andrew disrupted data collection and caused extensive damage to local natural and human resources (Pimm et al., 1994; Tilmant et al., 1994). Our objectives are to: 1) summarize and identify significant changes in recreational landings, 2) compare spearfishing to other recreational fishing modes in terms of selectivity and quantity of landings, and 3) compare recreational landings with fishery-independent, visual abundance estimates made by National Marine Fisheries Service (NMFS) divers.

Douglas E. Harper (Doug.Harper@noaa.gov) and James A. Bohnsack are with Southeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149. Brian R. Lockwood is with the Biscayne National Park, National Park Service, US Department of Interior, 9700 S.W. 328th Street, Homestead, FL 33033.

Materials and Methods

Creel census interviews were conducted by BNP personnel and volunteers using standardized data collection procedures (Davis and Thue, 1979). Data collection included a fishing party trip interview and biological sampling of landings conducted at the conclusion of a recreational fishing trip. Anglers were asked to indicate where they fished based on a map showing areas or zones used to partition Biscayne National Park and surrounding waters (Fig. 1). Statistical fishing areas 20 through 24 were added after 1983 as the result of a park boundary extension. Interview data collected included: date of trip, trip hours, number of anglers, hours fished, number, spe-

[1] Tilmant, J. T., and R. Stone. 1984. Reef fish harvest trends, Biscayne National Park Dade County, Florida. *In* 1984 Stock Assessment Workshop. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Ser., Southeast Fish. Sci. Cent., Miami, Fla., 26 p.

cies, and lengths of fish caught, number and species of fish released, preferred species, area fished, angler residence, origin of trip, and fishing party composition. Biological sampling consisted of taking fork or total length measurements of selected organisms in landings. Some length measurements taken during the first two years (1976 and 1977) were specified only at the family level.

Fishing party composition was classified by the interviewer into one of seven possible fishing categories: skilled, family, novice, sustenance (food), spearfishing, lobster diving, and other. Skilled anglers demonstrated expertise in several ways, such as knowledge of park waters, fishing experience, fishing rods rigged with appropriate artificial lures, or fishing in a specialized manner for particular fish. Novice fishermen had little experience fishing or had little experience in the BNP. The family designation applied to groups of adults and children or to groups of adults whose primary interest was other than fishing. Sustenance fishermen were those primarily fishing for food and tended to keep everything caught. Diving parties were classified according to whether the primary purpose was spearfishing or catching spiny lobster, *Panulirus argus*. Divers were not classified in terms of experience (novice or skilled) or purpose (recreation or food).

Data from January 1976 through August 1991 were entered, stored, and analyzed using a Wang[2] computer database at the Everglades National Park (ENP) approximately 30 miles from BNP headquarters. This computer system became obsolete and inoperative before its scheduled replacement. In November 1993, a backup copy (MS DOS format[2]) of all computerized records in the BNP Recreational Creel Census Database was provided to NMFS. The backup consisted of twelve 3.5" high density diskettes with two ASCII data files of recreational interviews (7.1Mb) and fish lengths (5.7Mb). The Fish Length file contained length measurement records of individual fish and spiny lobster as well as data fields for date, species, and interview number. The Recreational Interviews dataset contained all other information provided during each interview. Interview number was the relational field that linked the two datasets.

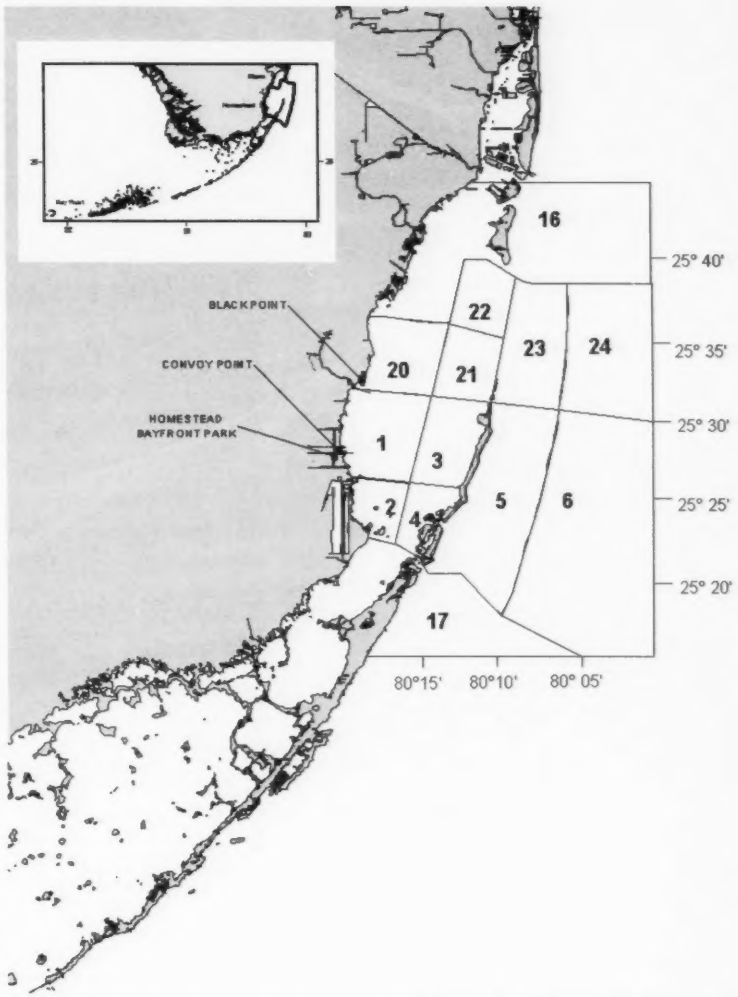

Figure 1.—The 13 statistical areas for reporting fishing trips in Biscayne National Park and surrounding south Florida waters. The inset shows the location of the Park in southern Florida.

The data were reformatted and edited by converting the two ASCII files into two SAS files (version 6.04)[2]. Data were verified and edited for obvious minor data entry errors using the exploratory data analysis and summarization procedures of the SAS System. These error corrections included: reconciliation of duplicate interview numbers and interviews, unrealistic or out of bounds dates and fish sizes, duplicate species kept and released data within a given interview, and some errors in record formatting. Although most data entry errors were in-

[2] Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service or the National Park Service.

tuitively corrected, some (< 1 % of total) questionable or unidentifiable data elements remained unresolved. These involved coded variables for area fished, angler residence, interview location, trip origin, and species which could not be verified. For the purposes of this report, unidentifiable species codes were recoded to miscellaneous fish while all other unresolvable data elements were set to missing variables.

Annual mean landings-per-unit-of-effort (LPUE) and catch-per-unit-of-effort (CPUE) were calculated for selected species. In this report "catch" refers to all organisms caught by recreational fishing while "landings" refers only to organisms caught and brought to shore. "Catch" comprises landings plus organisms reported caught but not brought back to shore, including organisms released (if alive), discarded (if dead), used for bait, or consumed at sea. Fishing effort was measured by angler-hour or trip. Annual rates (fish-per-angler-hour) were obtained using a mean of ratios estimator approach (Malvestuto, 1983) by averaging calculated rates of individual trips successful for the given species during a calendar quarter and then averaging the four quarters. This method was used in previous studies of recreational fisheries in southern Florida (Rutherford et al., 1989a,b; Tilmant et al. 1989).

Scientific and common names of fishes used in this report are according to Robins et al. (1991). Weights were estimated for individual fish by converting measured length to weight according to species specific conversion formulae (Bohnsack and Harper, 1988). Zone usage was analyzed by number of trips and landings. For analytical purposes, trip and landings data were divided equally between relevant zones for interviews indicating use of more than one zone.

A comparison of angling and spearfishing was made for the six most commonly speared species based on mean annual landed fish weight and mean annual total landings per trip. Because data for some species were only collected at the family level from 1976 thru 1978, these years were dropped from some analyses.

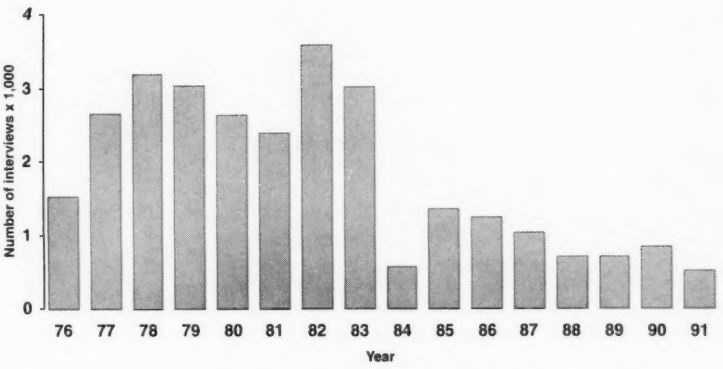

Figure 2.—Number interviews per year (January 1976 through July 1991) for the Biscayne National Park Sportfishing Creel Census.

Results

The BNP Recreational Creel Census Database contained 28,923 interviews completed between January 1976 and July 1991. The mean number of interviews conducted per year was 1,807 with a maximum of 3,587 in 1982 and a minimum of 511 in 1991 (through July only) (Fig. 2). The number of annual interviews dropped significantly after 1983, the second half of the survey period.

Interviews were weighted toward weekends (26,252 or 90.8%), followed by weekdays (2,035 or 7.0%) and holidays (611 or 2.1%). Most interviews (24,768 or 85.7%) were completed during the afternoon between 1:00 and 5:00 when most fishermen were returning to the dock. Over 98% of the interviews were conducted from two locations: Convoy Point (26,037 or 90.0%), the location of BNP headquarters, and Homestead Bayfront Park (2,448 or 8.5%) (Fig. 1). Only 28 interviews reported Black Point Marina as the trip origination site, and those were primarily lobster trips. The high probability of being sampled or encountering a ranger at Convoy Point may have biased the data toward anlers who were particularly conscious of fisheries regulations.

Fishing Party Composition and Species Preferences

Fishing party composition by percentage of total interviews in decreasing order were: skilled, family, novice, spearfishing, lobstering, food, and other (Table 1). During the survey period, the percentage of party types in the food category increased, while the novice category decreased (Fig. 3). The spearfishing component tended to remain fairly stable throughout the survey period, averaging 12% (from 7 to 16%) of the interviewed trips. Composition among fishing groups may have some bias, however, particularly with regard to inflated sampling of lobster fishermen because of concerted sampling effort during the beginning of lobster season and during the annual 2 day spiny lobster recreational miniseason. Also, large changes in party classification for novice and skilled categories observed from 1987 through 1990 may reflect changes in personnel conducting interviews.

Recreational anglers indicated a preference for 66 taxa (Table 2). Excluding the miscellaneous category, the favorite fishing targets by party type or composition were: dolphin, *Coryphaena hippurus*, for skilled recreational, food, family, and novice anglers; unidentified snappers, *Lutjanus* spp., for fishermen classified as "other"; hogfish, *Lachnolaimus maximus*, for spearfishermen; and spiny lobster for divers. For all party types combined, almost half of the interviews (13,847 or 47.9%) indicated no preference for particular species. The next most preferred target categories along with number and percentage of total interviews were: dolphin

Table 1.—Total landings and reported releases in numbers by species or higher taxa by fishing party type in the Biscayne National Park sportfishing creel census (n = 28,923 recreational fishing trips sampled from January 1976 through July 1991).

Family	Scientific name	Common name	Skilled recreational		Family		Novice		Spearfishing		Diving lobster		Food		Other		All types	
			Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released
Orectolobidae, Carpet sharks																		
1	*Ginglymostoma cirratum*	Nurse shark	18	58	11	29	5	26	8				12	12			54	125
Carcharhinidae, Requiem sharks																		
2	*Carcharhinus falciformis*	Silky shark	1	1													1	1
3	*Carcharhinus limbatus*	Blacktip shark	9	31	3	1	2	1					2	5			16	38
4	*Carcharhinus* spp.	Unidentified shark	45	133	11	33	12	45	8	1			17	25	1	1	94	238
5	*Negaprion brevirostris*	Lemon shark	10	7	1			1						1			11	9
Sphyrnidae, Hammerhead sharks																		
6	*Sphyrna mokarran*	Great hammerhead	3	9	1	7	2	13					10	1	2		18	30
7	*Sphyrna tiburo*	Bonnethead	14	24	7	9	2	3	1				11	11			35	47
Dasyatidae, Stingrays																		
8	*Dasyatis* spp.	Unidentified stingray		27		25		19	2				1	7			3	78
Elopidae, Tarpons																		
9	*Elops saurus*	Ladyfish	15	188	8	38	9	14					18	32			50	272
10	*Megalops atlanticus*	Tarpon	4	30	1	6	5	4					2	5			12	45
Albulidae, Bonefishes																		
11	*Albula vulpes*	Bonefish	40	233	8	8	6	4	1		20		1	1			76	246
Muraenidae, Morays																		
12	*Gymnothorax moringa*	Spotted moray	1	22		5		11					1	10			2	48
13	*Gymnothorax* spp.	Unidentified moray	8	201		67	3	57	5				5	36			21	361
Clupeidae, Herrings																		
14	N.A.	Unidentified herring			3								524				527	
Synodontidae, Lizardfishes																		
15	*Synodus* spp.	Unidentified lizardfish	6	107	9	61	4	40					4	18			23	226
Ictaluridae, Bullhead catfishes																		
16	N.A.	Unidentified catfish				3			1								1	3
Ariidae, Sea catfishes																		
17	*Arius felis*	Hardhead catfish	4	12		5											4	17
Exocoetidae, Flyingfishes/halfbeaks																		
18	*Hemiramphus brasiliensis*	Ballyhoo	1,980	43	345	15	211	19					130	4	12		2,678	81
Belonidae, Needlefishes																		
19	*Strongylura* spp.	Unidentified needlefish	30	92	10	101	7	73					6	11			53	277
20	*Tylosurus crocodilus*	Houndfish	10	50	12	34	9	19	5				26	34			62	137
Holocentridae, Squirrelfishes																		
21	*Holocentrus adscensionis*	Squirrelfish	13	9	7	12	4	37	1				27	7			52	65
22	*Holocentrus* spp.	Unidentified squirrelfish	3										1				4	
Aulostomidae, Trumpetfishes																		
23	*Aulostomus maculatus*	Trumpetfish	1	6	1	1		2	2								4	9
Centropomidae, Snooks																		
24	*Centropomus ensiferus*	Swordspine snook	6	22					1								7	22
25	*Centropomus undecimalis*	Common snook	48	110	1	2			1		1		1	3			52	115
Serranidae, Sea basses																		
26	*Diplectrum formosum*	Sand perch	266	354	491	390	512	524	2			2	397	100			1,668	1,370
27	*Epinephelus adscensionis*	Rock hind	103	36	42	23	23	18	23				27	32			218	109
28	*Epinephelus cruentatus*	Graysby	164	108	154	120	73	8	42				222	151	7		662	387
29	*Epinephelus drummondhayi*	Speckled hind	2										1				3	
30	*Epinephelus flavolimbatus*	Yellowedge grouper		5	4			1	8								12	6
31	*Epinephelus fulvus*	Coney	13	14	6	4	5	1	3				3	4			30	23
32	*Epinephelus guttatus*	Red hind	253	154	123	90	74	95	69		2		105	54	1		627	393
33	*Epinephelus inermis*	Marbled grouper							1								1	
34	*Epinephelus itajara*	Jewfish	1			1		3	6		1						8	4
35	*Epinephelus morio*	Red grouper	1,017	283	403	131	275	26	851	1	26		422	177	10	25	3,004	643
36	Epinephelus striatus	Nassau grouper	369	72	132	41	141	31	809		22	1	133	48	4		1,610	193
37	*Mycteroperca bonaci*	Black grouper	351	59	122	48	88	10	765	1	9		92	34	2		1,429	152
	Mycteroperca interstitialis	Yellowmouth grouper	30		8		5		14		1		6				64	
39	*Mycteroperca microlepis*	Gag	295	81	94	34	54	15	77		1		63	34			584	164
40	*Mycteroperca phenax*	Scamp	12				3		6								21	
41	*Mycteroperca venenosa*	Yellowfin grouper	27	2	5		2	1	30				1	1			65	4
42	*Paranthias furcifer*	Creole-fish	3				2										5	
43	N.A.	Unidentified grouper	2,198	1,230	693	897	709	552	1,812	16	102	1	719	529	43	19	6,276	3,244

Continued

Table 1.—(Continued).

Family	Scientific name	Common name	Skilled recreational		Family		Novice		Spearfishing		Diving lobster		Food		Other		All types	
			Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released
Grammistidae, Soapfishes																		
44	*Rypticus saponaceus*	Greater soapfish		1	1												1	1
Priacanthidae, Bigeyes																		
45	*Priacanthus arenatus*	Bigeye	277	43	115	60	103	16	41		3		227	24	1		767	143
46	N.A.	Unidentified bigeye	4			15			1		2						7	15
Malacanthidae, Tilefishes																		
47	*Malacanthus plumieri*	Sand tilefish	65	186	54	99	49	135	2				43	50			213	470
48	N.A.	Unidentified tilefish			5	1	5										10	1
Pomatomidae, Bluefishes																		
49	*Pomatomus saltatrix*	Bluefish	72	17	10		18	13					9	1		15	109	46
Rachycentridae, Cobias																		
50	*Rachycentron canadum*	Cobia	12	3	1								3				16	3
Echeneidae, Remoras																		
51	*Echeneis naucrates*	Sharksucker	1	10	3	2		5					3	8			7	25
Carangidae, Jacks																		
52	*Alectis ciliaris*	African pompano	22	2	8		8	1	3				3				44	3
53	*Caranx bartholomaei*	Yellow jack	123	67	65	4	18	14	175		3		126	3	7	1	517	89
54	*Caranx crysos*	Blue runner	1,071	892	1,019	715	532	432	67	43	6		1,173	501	5		3,873	2,583
55	*Caranx hippos*	Crevalle jack	92	201	83	101	104	62	20				83	70			382	434
56	*Caranx latus*	Horse-eye jack	8	9	8	2	8		2				4	4			30	15
57	*Caranx ruber*	Bar jack	42	65	15	11	35	7	34	1			27	4			153	88
58	*Caranx* spp.	Unidentified jack	283	676	176	393	196	356	120	1	11		215	75	5		1,006	1,501
59	*Decapterus macarellus*	Mackerel scad	36	7	3								12	4			51	11
60	*Elagatis bipinnulata*	Rainbow runner	11	10	7	1	1	12	4				1				24	23
61	*Oligoplites saurus*	Leatherjacket	6	3	10	2	20	1					16	13			52	19
62	*Selene vomer*	Lookdown	76	7	29	1	1	1					34	1			140	10
63	*Seriola dumerili*	Greater amberjack	168	46	26	27	15	9	59	1			12	3			280	86
64	*Seriola rivoliana*	Almaco jack	4		9								5	11			18	11
65	*Trachinotus carolinus*	Florida pompano	3	1			2	1					2	1			7	3
66	*Trachinotus falcatus*	Permit	10	7	3		5		16		2		1				37	7
Coryphaenidae, Dolphins																		
67	*Coryphaena equisetis*	Pompano dolphin	1										1				2	
68	*Coryphaena hippurus*	Dolphin	13,283	408	1,525	47	639	15	30	4			1,845	71	12	3	17,334	548
Lutjanidae, Snappers																		
69	*Etelis oculatus*	Queen snapper			7									3			7	3
70	*Lutjanus analis*	Mutton snapper	1,326	127	463	97	202	23	364		12		434	99	6	10	2,807	356
71	*Lutjanus apodus*	Schoolmaster	205	25	129	29	42	20	252		5		132	32	3		768	106
72	*Lutjanus buccanella*	Blackfin snapper	3		2		1		1								7	
73	*Lutjanus campechanus*	Red snapper	14	1	1	7	2	1									17	9
74	*Lutjanus cyanopterus*	Cubera snapper	2		3	1			16								21	1
75	*Lutjanus griseus*	Gray snapper	9,976	4,889	5,279	2,839	3,792	1,725	1,432	16	120	35	7,016	2,215	73	27	27,688	11,746
76	*Lutjanus jocu*	Dog snapper	9	1	13	2	15		63		1		7				108	3
77	*Lutjanus mahogoni*	Mahogany snapper	13	1	2				10				6	2			31	3
78	*Lutjanus* spp.	Unidentifed snapper	5,959	1,340	2,642	1,041	2,348	878	718	11	46	15	3,087	230	95	3	14,895	3,518
79	*Lutjanus synagris*	Lane snapper	609	79	239	71	258	51	21				435	159			1,562	360
80	*Lutjanus vivanus*	Silk snapper	9	2					3				4				16	2
81	*Ocyurus chrysurus*	Yellowtail snapper	7,217	4,461	2,074	2,395	1,831	1,212	178	7	18		3,107	2,077	5	10	14,430	10,162
82	*Rhomboplites aurorubens*	Vermilion snapper	26	10	11				11								48	10
Lobotidae, Tripletails																		
83	*Lobotes surinamensis*	Tripletail	42	6	2		4						6				54	6
Gerreidae, Mojarras																		
84	*Gerres cinereus*	Yellowfin mojarra	2	2	5	5	28	11	1				29	1			65	19
Haemulidae, Grunts																		
85	*Anisotremus surinamensis*	Black margate	27	2	23	1	10	7	147		6		42	13			255	23
86	*Anisotremus virginicus*	Porkfish	51	6	40	28	43	32	18				95	25			247	91
87	*Haemulon album*	Margate	173	35	108	8	32	12	75		5		134	18			527	73
88	*Haemulon aurolineatum*	Tomtate	35		37	2	25	34					99	5			196	41
89	*Haemulon carbonarium*	Caesar grunt	22	1	14		3	3	8				24	2			71	6
90	*Haemulon chrysargyreum*	Smallmouth grunt			3		4						1				8	
91	*Haemulon flavolineatum*	French grunt	104	64	62	21	48	7	5				43				262	92
92	*Haemulon macrostomum*	Spanish grunt	6	10	17		4		20				28	13			75	23
93	*Haemulon parrai*	Sailor's choice	210	172	208	95	103	74	5				160	45			686	386
94	*Haemulon plumieri*	White grunt	12,509	6,911	8,850	3,722	6,323	3,463	309	92	26	15	13,262	3,409	89	48	41,368	17,660

Continued

Table 1.—(Continued).

Family	Scientific name	Common name	Skilled recreational		Family		Novice		Spearfishing		Diving lobster		Food		Other		All types	
			Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released
95	*Haemulon sciurus*	Bluestriped grunt	3,442	1,762	2,427	1,332	1,723	893	202	4	6	1	2,841	538	51	16	10,692	4,546
96	*Haemulon* spp.	Unidentified grunt	5,761	8,711	3,448	5,846	3,606	5,707	277	125	25	27	5,706	2,216	223	60	19,046	22,692
97	*Haemulon striatum*	Striped grunt	4		7		3	9	1				24	2			39	11
98	*Orthopristis chrysoptera*	Pigfish	17	4	19	14	10	12					30				76	30
Sparidae, Porgies																		
99	*Archosargus probatocephalus*	Sheepshead	68	1	20	5	21	2	16				26	5			151	13
100	*Archosargus rhomboidalis*	Sea bream	71	32	55	46	30	20	4				56	13			216	111
101	*Calamus arctifrons*	Grass porgy	6		35		9	6	1				9	1			60	7
102	*Calamus bajonado*	Jolthead porgy	4,708	571	1,584	213	1,676	340	95		11		2,576	74	24		10,674	1,198
103	*Calamus calamus*	Saucereye porgy	500	15	232	36	206	12	12		3		258	24	5		1,216	87
104	*Calamus nodosus*	Knobbed porgy	2		3								5				10	
105	*Calamus proridens*	Littlehead porgy	3		2		1						41	2			47	2
106	*Calamus* spp.	Unidentifed porgy	30	15	37	47	11	17					8	9		8	86	96
107	*Lagodon rhomboides*	Pinfish	1,354	2,091	627	1,070	569	1,040	3				762	400			3,315	4,601
Sciaenidae, Drums																		
108	*Cynoscion nebulosus*	Spotted seatrout	1,036	477	164	96	182	96					122	97			1,504	766
Mullidae, Goatfishes																		
109	*Mulloidichthys martinicus*	Yellow goatfish	1	4		1			4				1				6	5
110	*Pseudupeneus maculatus*	Spotted goatfish	2	3	1		2				1		2	1			8	4
Kyphosidae, Sea chubs																		
111	*Kyphosus incisor*	Yellow chub	11		25	9	8	1	3				4				51	10
112	*Kyphosus sectatrix*	Bermuda chub	118	62	98	29	122	34	30		3		86	34			457	159
113	*Kyphosus* spp.	Unidentified chub	15	15	24	7		11	3				39	8			81	41
Ephippidae, Spadefishes																		
114	*Chaetodiperus faber*	Atlantic spadefish	1	1	5	4	1		37		4		3	1			51	6
Pomacanthidae, Angelfishes																		
115	*Holacanthus ciliaris*	Queen angelfish		2	2	1			2					1			4	4
116	*Pomacanthus arcuatus*	Gray angelfish							2								2	
117	*Pomacanthus paru*	French angelfish	1														1	
118	N.A.	Unidentified anglefish	5	46	10	28	6	24	33				8	21			62	119
Pomacentridae, Damselfishes																		
119	*Abudefduf saxatilis*	Sergeant major		4		11	1										1	15
Labridae, Wrasses																		
120	*Bodianus rufus*	Spanish hogfish	8	4	9		2		15		1		5				40	4
121	*Halichoeres bivittatus*	Slippery dick	5	2	6				11				5				27	2
122	*Halichoeres radiatus*	Puddingwife	12	4	11	43	18	18	1				33	47		1	75	113
123	*Halichoeres* spp.	Unidentified wrasse	7	38	28	35	16	32	1				11	16			63	121
124	*Lachnolaimus maximus*	Hogfish	1,046	145	318	73	260	15	13,286	15	380		429	97	43	4	15,762	349
Scaridae, Parrotfishes																		
125	*Scarus guacamaia*	Rainbow parrotfish	3	5	1	6	4	3	5				4				17	14
126	N.A.	Unidentified parrotfish	36	343	70	200	39	114	71	1	1	1	71	95		2	288	756
Mugilidae, Mullets																		
127	*Mugil* spp.	Unidentified mullet	88	7	8	1							136				232	8
Sphyraenidae, Barracudas																		
128	*Sphyraena barracuda*	Great barracuda	2,890	2,205	911	515	761	523	161	16	19	8	1,173	296	41	2	5,956	3,565
129	*Sphyraena picudilla*	Southern sennet	1														1	
Acanthuridae, Surgeonfishes																		
130	*Acanthurus bahianus*	Ocean surgeon	2	7	3	2	3	1	2				1	1			11	11
131	*Acanthurus chirurgus*	Doctorfish	11	6	10	3	5	1					17	12			43	22
132	*Acanthurus coeruleus*	Blue tang	1	1	11	1		3	1				1	1			14	6
Scombridae, Mackerels/Tunas																		
133	*Acanthocybium solandri*	Wahoo	123	2	17		3		1				17	1	1	1	162	4
134	*Euthynnus alletteratus*	Little tunny	70	17	10	8	1	4					29	18			110	47
135	*Katsuwonus pelamis*	Skipjack tuna	23	2	5		3						10	1			41	3
136	*Sarda sarda*	Atlantic bonito	287	177	45	36	50	32	2				12	17		1	396	263
137	*Scomberomorus cavalla*	King mackerel	165	10	18	9	16		2				28				229	19
138	*Scomberomorus maculatus*	Spanish mackerel	182	7	32	1	42	9	21	1			20	4			297	22
139	*Scomberomorus regalis*	Cero mackerel	618	16	150	13	109	4	53		2		142	7			1,074	40

Continued

Table 1.—(Continued).

Family	Scientific name	Common name	Skilled recreational		Family		Novice		Spearfishing		Diving lobster		Food		Other		All types	
			Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released	Landed	Released
140	*Thunnus albacares*	Yellowfin tuna	1														1	
141	*Thunnus atlanticus*	Blackfin tuna	37	3	7	2	3						2	2			49	7
142	*Thunnus obesus*	Bigeye tuna				2							3				3	2
143	*Thunnus* spp.	Unidentified tuna	278	41	50	17	90	19	14			2	23	2	1		456	81
Xiphiidae, Swordfishes																		
144	*Xiphias gladius*	Swordfish											6				6	
Istiophoridae, Billfishes																		
145	*Istiophorus platypterus*	Sailfish	65	17	4	2	4						2	2			75	21
146	*Makaira nigricans*	Blue marlin	1														1	
147	N.A.	Unidentified billfish	353														353	
Scorpaenidae, Scorpionfishes																		
148	*Scorpaena* spp.	Unidentified scorpionfish		21	1	12	1	7					1	6			3	46
Triglidae, Searobins																		
149	*Prionotus* spp.	Unidentified searobin		3		3			1					1			1	7
Bothidae, Lefteye flounders																		
150	*Bothus lunatus*	Peacock flounder									1						1	
151	N.A.	Unidentified lefteye flounder	1	1	4	2	8		4				2				19	3
Balistidae, Leatherjackets																		
152	*Aluterus scriptus*	Scrawled filefish	1	3	3		2	1					3	3			9	7
153	*Balistes capriscus*	Gray triggerfish	70	65	91	42	57	12	6		1		95	28	3		323	147
154	*Balistes vetula*	Queen triggerfish	29	32	14	14	16	10	4				38	16	1		102	72
155	*Cantherhines pullus*	Orangespotted filefish	0	24	5	7	1	3	2				1				9	34
156	*Canthidermis sufflamen*	Ocean triggerfish	220	126	130	55	109	51	32	2	4		168	51	10		673	285
157	N.A.	Unidentifed filefish	6	34	4	13	2	10	1				8	2			21	59
Ostraciidae, Boxfishes																		
158	*Lactophrys* spp.	Unidentified boxfish	11	24	23	61	14	19	4		1		23	16			76	120
159	*Lactophrys trigonius*	Trunkfish	7	10	2	6	2	5					4	3			15	24
Tetraodontidae, Puffers																		
160	*Diodon hystrix*	Porcupinefish				15	1										1	15
161	*Sphoeroides* spp.	Unidentified puffer	7	84	11	108	8	130	1				7	57			34	379
162	N.A.	Unidentified fishes	1,088	1,036	304	625	393	733	139	4	19	2	1,100	130	21	6	3,064	2,536
Invertebrates																		
163	*Calinectes sapidus*	Bluecrab	221	4	82	13	34	3			48		90	8			475	28
164	*Menippe mercenaria*	Stone crab									3		1			1	4	1
165	*Mithrax* spp.	Unidentified spidercrab									1						1	
166	*Panulirus argus*	Caribbean spiny lobster	1,902	1,882	286	141	548	635	2,623	2,014	21,938	17,813	386	580	35	4	27,718	23,069
167	*Panulirus guttatus*	Spotted lobster	4		4				10		21						39	
168	*Pennaeus duorarum*	Pink shrimp			30												30	
169	*Scyllarides aequinoctialis*	Shovel-nosed lobster	1						13		25						39	
170	*Strombus gigas*	Queen conch	136		50		86		1,018	50	2,227	77			10		3,527	127
	Total		88,765	44,843	37,718	24,967	30,022	20,927	27,015	2,427	25,196	18,000	51,700	15,546	852	268	261,268	126,978
	No. interviews		9,244	9,244	5,199	5,199	5,071	5,071	3,473	3,473	3,142	3,142	2,647	2,647	147	147	28,923	28,923
	Avg. trip landings		9.60		7.25		5.92		7.78		8.02		19.53		5.80		9.03	
	% Total landings		34.0%		14.4%		11.5%		10.3%		9.6%		19.8%		0.3%			
	Avg. Trip Releases			4.85		4.80		4.13		0.70		5.73		5.87		1.82		4.39
	% Total Releases			35.3%		19.7%		16.5%		1.9%		14.2%		12.2%		0.2%		

(4,315 or 14.9%), spiny lobster (3,381 or 11.7%), unidentified snappers (1,501 or 5.2%), unidentified groupers (1,375 or 4.8%), and hogfish (880 or 3.0%).

Landings

A total of 261,268 fish and shellfish representing 170 species or higher taxa were recorded in recreational creel samples (Table 1). Five species or higher taxa accounted for more than 50% of total number of organisms landed: white grunt, *Haemulon plumieri* (15.8%); spiny lobster (10.6%); gray snapper, *Lutjanus griseus* (10.6%); unidentified grunts, *Haemulon* spp. (7.3%); and dolphin (6.6%).

Average annual LPUE for all 28,923 interviews was 4.77 fish/angler/trip (from 3.80 in 1991 to 5.83 in 1981) (Fig. 4). Mean LPUE increased from 1976 through 1981 and then declined with large fluctuations between 1984 and 1991. The 95% confidence intervals suggest that observed significant drops in landings per angler-trip during 1985 and 1986 were unlikely to be anomalies caused by smaller sample sizes. We conclude that this drop was most likely the temporary result of several new recreational fishery regulations. During the study period, several landings regulations were implemented that may have influenced landings. In September 1983 minimum size limits of 12 inches (30.5 cm) were established for black grouper, *Mycteroperca bonaci*; and yellowtail snapper, *Ocyurus crysurus*; for Federal waters (>3 n.mi. from land), areas mostly outside the study area. On 29 July 1985, Florida established minimum size limits much more likely to influence BNP landings since they applied to state waters (< 3 n.mi. from land). These new minimum size limits applicable to state waters were 12 inches (30.5 cm) for yellowtail snapper, and mutton snapper, *Lutjanus analis*; and 18 inches (45.7 cm) for black grouper; yellowfin grouper, *Mycteroperca venenosa*; gag, *M. microlepis*; red grouper, *Epinephelus morio*; and Nassau grouper, *E. striatus*. In December 1986, bag limits were established of 10 snappers and 5 groupers per angler per day. In February 1990, Florida added or increased minimum size limits to 8 inches (20.3 cm) for vermilion snapper, *Rhomboplites aurorubens*; and lane snapper, *L. synagris*; 10 inches (25.4 cm) for gray snapper, *L. griseus*; and schoolmaster, *L. apodus*; 20 inches (50.8 cm) for scamp, *M. phenax*; yellowmouth grouper, *M. interstitalis*; black, gag, red, yellowfin, and Nassau groupers; and 28 inches (71.1 cm) for greater amberjack, *Seriola dumerili*. Again, the reported average annual landings per angler-trip declined significantly in 1990 and 1991, the years during and following the application of new minimum size limits (Fig. 4).

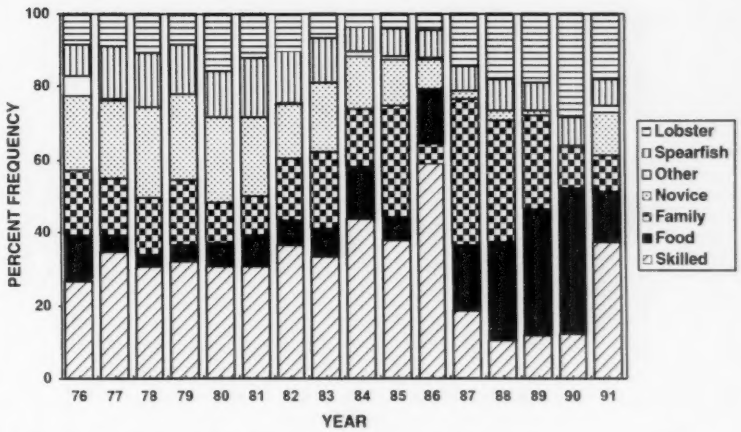

Figure 3.—Composition of recreational fishing trips by party type (January 1976–July 1991). Sample sizes are shown in Figure 2.

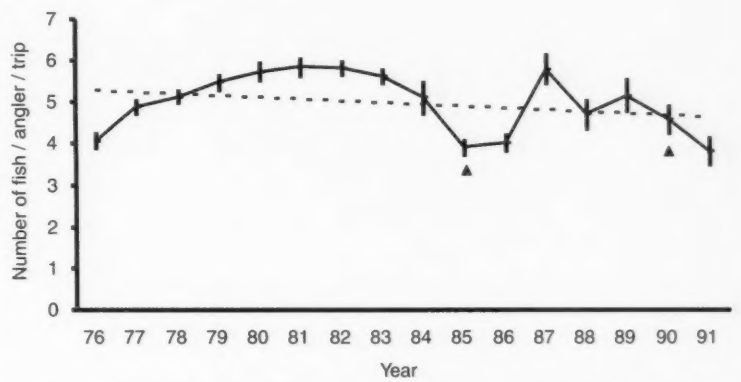

Figure 4.—Mean number of fish landed per person per trip (± 95% C.I.) for the Biscayne National Park Sportfishing Creel Census. The dotted line shows the linear trend for 28,923 trip interviews. Arrows show when multiple minimum size limits became effective in Florida. Sample sizes are shown in Figure 2.

Tilmant (1981) reported an inverse relationship between average landings and total trips. Years with more trips had lower average LPUE values while years with fewer trips had higher LPUE values. Thus, the decline in LPUE between 1982 and 1991 also may reflect an increased total number of fishing trips, although data were not available to estimate total annual number of trips. Previous studies used trailer counts to estimate total fishing trips based upon a correlation between trailers and aerial counts of fishing vessels, but these data were unavailable after 1985. Boat trailer counts and total fishing trips are known to be highly af-

fected by weather, day of the week, holiday occurrence, and special events, such as the opening of spiny lobster season. In general, more fishing trips are made during special marine-related events or on the weekends with good boating conditions, while fewer fishing trips occur during major local sporting events or inclement weather conditions. Also, without information on the total number of trips, we were not able to estimate total annual catch or landings in BNP.

Table 2.—Species preferences as a percent of interviews (n = 28,923) by recreational fishing party type. Species listed in less than 1% of interviews by party type are shown by **. Scientific names are shown in Table 1.

Common name	Skilled recreational	Family	Novice	Spear fishing	Diving lobster	Food	Other	All types
Atlantic bonito	**	**						**
Atlantic spadefish	**							**
Ballyhoo	**							**
Bigeye	**							**
Black grouper				**				**
Blue runner	**	**	**					**
Bluecrab	**		**		**	**		**
Bluefish	**		**					**
Bluestriped grunt		**						**
Bonefish	5.7%	**	**		**	**		2.1%
Caribbean spiny lobster	2.0%	**	1.8%	5.9%	88.9%	2.6%	4.8%	11.7%
Cero mackerel	**	**	**			**		**
Cobia	**							**
Common snook	**	**	**	**		**		**
Creole wrasse						**		**
Crevalle jack			**					**
Cubera snapper	**					**		**
Dolphin	30.4%	11.7%	9.3%	**	**	15.2%	8.2%	14.9%
French grunt	**							**
Gag	**							**
Gray snapper	2.6%	2.5%	1.9%	**		3.9%	**	2.0%
Gray triggerfish		**						**
Great barracuda	2.5%	2.3%	1.6%	**		3.0%	5.4%	1.8%
Greater amberjack	**	**	**			**		**
Hogfish	**	**	**	23.1%	**	**	**	3.0%
Jolthead porgy	**	**	**			**		**
King mackerel	**	**	**			**	**	**
Longnose sucker	**							**
Lookdown	**							**
Mutton snapper	1.7%	**	**	**		1.1%	**	**
Nassau grouper				**				**
Nurse shark			**					**
Painted wrasse	**			**				**
Permit	**		**					**
Pinfish			**					**
Queen conch	**			**	3.6%	**		**
Red grouper	**	**		**				**
Red snapper	**	**	**					**
Sailfish	1.7%	**	**	**	**	**	1.4%	**
Sand perch	**	**	**			**		**
Schoolmaster	**							**
Sheepshead	**					**		**
Shovel-nosed lobster	**			**	**			**
Skipjack tuna	**							**
Spanish mackerel	**	**	**			**		**
Spottail pinfish		**						**
Spotted seatrout	2.3%	1.4%	2.0%			1.2%	1.4%	1.4%
Stone crab					**			**
Swordspine snook	**							**
Tarpon	**	**	**			**		**
Unidentified porgy	**	**	**			**	**	**
Unidentified snapper	5.5%	6.1%	6.2%	3.0%	**	8.7%	15.0%	5.2%
Unidentified billfishes	**	**	**					**
Unidentified dolphin	**							**
Unidentified fishes	35.5%	67.6%	69.3%	52.7%	6.2%	54.9%	49.7%	47.9%
Unidentified groupers	4.6%	3.1%	3.8%	13.2%	**	4.3%	8.8%	4.8%
Unidentified grunt	**	**	**	**		1.1%	**	**
Unidentified jack	**	**	**	**		**	**	**
Unidentified shark	**	**	**	**		**		**
Unidentified snook	**							**
Unidentified tuna	1.1%	**	**			**	**	**
Unidentified wrasse				**				**
Wahoo	**	**				**		**
White grunt	**	**	**			**		**
Yellow jack				**				**
Yellowtail snapper	**	**	**	**	**	1.2%		**

An average of 9.03 finfish or shellfish were landed per trip for all interviews (Table 1). Parties classified in the "food" category had the highest average trip landings of 19.53, followed by skilled recreational (9.60), lobster diving (8.02), and spearfishing (7.78). Fishing parties classified as "other" had the lowest average landings of 5.80 per trip. The relative contribution by each party type to total numerical landings sampled was: skilled recreational (34.0%), food (19.8%), family (14.5%), novice (11.5%), spearfishing (10.3%), lobster diving (9.6%), and other (0.3%) (Table 1). The four angling party types showed broad overlap in landings composition (Table 1). Lobster diving and "other" categories were distinctive by landing very few species. Spearfishermen showed intermediate selectivity by concentrating on hogfish, groupers, jacks, snappers, and grunts (Table 1).

Releases

Recreational fishermen reported releasing 126,978 fish and shellfish in trip interviews, representing 147 species or higher taxa (Table 1). Five taxa accounted for approximately 67% of total organisms released: spiny lobster (18.2%), unidentified grunts (17.9%), white grunt (13.9%), gray snapper (9.3%), and yellowtail snapper (8.0%). The average trip release rate for all interviews was 4.39 fishes or shellfish per trip. Lobster divers reported more releases per trip (5.73) than any other fishing party type, probably because minimum size limits existed on spiny lobster throughout the study period. A total of 17,600 organisms released by lobster divers were mostly spiny lobster (97.8%). Spearfishing parties reported the fewest average releases per trip (0.70) reflecting the selectivity of their fishing gear and methods that target individual fishes. This number does not include organisms that may have escaped capture after being speared.

A comparison was made of landings and releases for the ten most commonly landed taxa (Table 3). The four most commonly landed taxa (white grunt, spiny lobster, gray snapper, and unidentified grunts) also ranked within the top ten released taxa. Only three of the top

ten landed species failed to rank within the top ten releases: dolphin (rank 19); hogfish (rank 29); and jolthead porgy, *Calamus bajonado* (rank 15). The release to landings ratio for all taxa was 0.49:1. The ratio was lowest for dolphin (0.03:1) and highest for unidentified grunts (1.19:1).

Length Measurements

A total of 70,687 length measurements were recorded, representing 149 taxa and 27.1% of all landings. The average annual number of organisms measured was 4,418 (range: 1,417 in 1991 to 7,049 in 1985). The percentage of total individuals measured was highly variable between species, ranging from 1.29% for unidentified grunts to 100% for 17 species or higher taxa. The 10 species with the most measured individuals were: spiny lobster (16,527), white grunt (10,125), gray snapper (8,756), hogfish (5,077), dolphin (4,911), yellowtail snapper (3,891), bluestriped grunt, *Haemulon sciurus* (3,348), red grouper (1,941), mutton snapper, (1,516), and great barracuda, *Sphyraena barracuda* (1,398).

Areas Fished

Trip interviews reported fishing activity in various spatial combinations of 13 zones used by the Park Service in southern Florida (Fig. 1, Table 4). The distribution of total trips and total landings among zones is shown in Figure 5. Spearfishing trips showed the most restrictive use patterns by concentrating 84% of their trips in areas 5 and 6. The remaining party types had similar patterns of area usage mostly concentrating in zones 2, 4, 5, and 6. Zones 5 and 6 accounted for most trips (57.5%) and landings (54.0%). Only 9.9% of trips and 11.0% of landings were reported from trips that visited multiple zones.

The areas with the highest mean total catch per trip were: Statistical Area 20—Biscayne Bay, northeastern corner of BNP (17.6 fish or shellfish per trip, SE = 4.7); Area 17—south of BNP (17.5 fish or shellfish per trip, SE = 0.8); Areas 2 and 4—Biscayne Bay, southern portion within BNP (17.0 fish or shellfish per trip, SE = 2.9). Although Area 20 had the highest catch compared with other areas, the sample size was small ($n = 47$) and the variability (SE = 4.7) was the largest computed for all areas. Statistical fishing areas 20 through 26 were added after 1983 as the result of a boundary extension for BNP (Table 5). In July 1984 southern Biscayne Bay (regions 1–4 and 20–22) were closed to spiny lobster fishing.

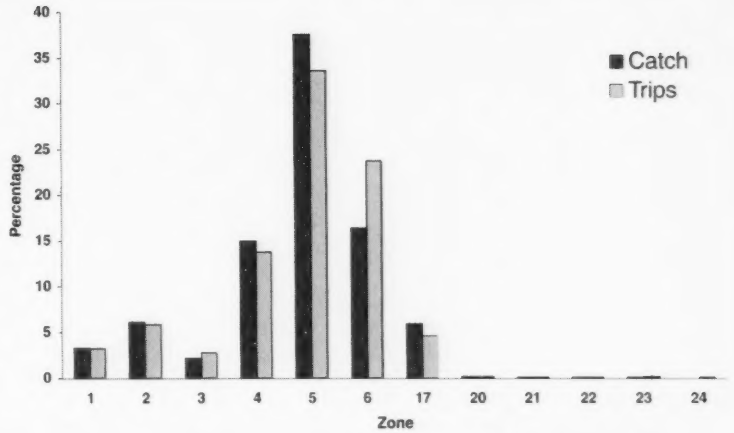

Figure 5.—Distribution by percentage of trips and catch (landings and releases) in BNP statistical reporting areas from 1976–1991 ($n = 28,923$ trips; 388,246 organisms).

Table 3.—Comparison of landings and releases for the 10 most commonly landed taxa.

	Landings			Releases			Release to landings ratio
Common name	Number	% Total	Rank	Number	% Total	Rank	
White grunt	41,368	15.83	1	17,660	13.91	3	0.43:1
Caribbean spiny lobster	27,718	10.61	2	23,069	18.17	1	0.83:1
Gray snapper	27,688	10.60	3	11,746	9.25	4	0.42:1
Unidentified grunts	19,046	7.29	4	22,692	17.87	2	1.19:1
Dolphin	17,334	6.63	5	548	0.43	19	0.03:1
Hogfish	15,762	6.03	6	349	0.27	29	0.02:1
Unidentified snappers	14,895	5.70	7	3,518	2.77	9	0.24:1
Yellowtail snapper	14,430	5.52	8	10,162	8.00	5	0.70:1
Bluestriped grunt	10,692	4.09	9	4,546	3.58	7	0.43:1
Jolthead porgy	10,674	4.09	10	1,198	0.94	15	0.11:1

Spearfishing

A total of 3,473 recreational spearfishing trips were sampled between January 1976 and July 1991 (mean 217 trips per year, range 37 for partial 1991 to 491 in 1982). Annual composition of sampled landings was determined for the 110 species or higher taxa recorded from spearfishing trips (Table 6). An average 7.78 organisms were landed per spearfishing trip (range 5.23 in 1986 to 9.71 in 1983) (Fig. 6). Spearfishing accounted for about 12.0% of the total fishing trips sampled but only 10.3% of the total number of organisms landed and 7.6% of all organisms caught ($n = 388,246$).

Spearfishing was more selective than angling. Hogfish accounted for almost half (49%) of the organisms speared (13,286 of 27,015) and 84.3% of the 15,762 hogfish landed. Speared hogfish averaged 35.06 cm FL (SD = 9.05 cm, Fig. 7). In 1994, after the study period, Florida enacted a 12 inch (30.5 cm) FL minimum size limit along with a daily bag limit of five hogfish per person. The median annual hogfish fork length over the study period was 33 cm (from 29 cm in 1976 to 36 cm in 1986, Fig. 8). A total of 34.8% of the measured hogfish were below 12 inches (30.5 cm) FL, the minimum size limit established after the study period.

Table 4.—Patterns of zone usage based on percentage of trips and catch numbers (landings + releases) reported in trip interviews by fishing party type from January 1976 through July 1991.

	Fishing party type															
	Experienced		Family		Novice		Spearfishing		Lobster diving		Food		Other		Total	
Fishing zones	% Trips	% Catch	% Trips	% Catch	% Trips	% Catch	% Trips	% Catch	% Trips	% Catch	% Trips	% Catch	% Trips	% Catch	% Trips	% Catch
Area 1	2.6	3.3	4.3	3.8	5.9	5.4	0.2	0.1	1.2	2.2	3.6	3.1	9.5	0.7	3.2	3.3
Area 2	5.4	5.4	8.7	8.4	8.0	7.6	0.4	0.4	1.7	3.0	9.3	8.6	8.2	4.8	5.8	6.1
Area 3	1.7	1.6	5.3	3.3	4.5	3.5	0.6	0.4	1.3	0.8	2.1	2.7	2.7	2.4	2.7	2.2
Area 4	10.0	11.7	20.2	20.2	18.9	18.6	4.1	3.0	16.5	23.3	14.0	13.7	17.7	16.4	13.8	15.0
Area 5	24.0	32.9	26.4	34.2	26.3	32.3	64.3	65.4	53.1	43.8	32.9	38.0	32.0	39.3	33.7	37.6
Area 6	38.0	23.8	16.7	11.0	18.3	11.9	21.5	21.3	8.5	6.5	20.7	14.3	13.6	12.8	23.8	16.4
Areas 1,2	0.6	0.8	0.8	0.7	0.9	0.9	0.1	0.0	0.3	0.4	0.9	0.9	2.0	9.2	0.6	0.8
Areas 1,3	0.3	0.2	0.3	0.4	0.5	0.3	0.0	0.0	0.2	0.1	0.3	0.4	0.7	0.2	0.3	0.3
Areas 2,4	0.9	0.8	1.3	1.4	1.0	0.7	0.1	0.0	0.4	0.7	0.8	2.1	0.0	0.0	0.8	1.0
Areas 3,4	0.5	0.5	1.3	1.0	1.1	0.6	0.2	0.2	0.3	0.4	0.5	0.4	0.7	0.4	0.7	0.5
Areas 1,2,3,4	0.3	0.2	0.3	0.2	0.7	0.5	0.0	0.1	0.1	0.1	0.2	0.1	7.5	5.1	0.4	0.2
Areas 3,5	0.3	0.3	0.6	0.5	0.4	0.4	0.1	0.0	0.1	0.2	0.5	0.6	0.0	0.0	0.3	0.4
Areas 4,5	2.3	2.4	2.7	3.0	2.3	2.5	1.1	0.8	2.7	3.0	2.6	3.2	0.0	0.0	2.3	2.6
Areas 3,4,5	0.3	0.3	0.4	0.5	0.4	0.4	0.1	0.0	0.2	0.2	0.5	0.5	0.7	1.0	0.3	0.4
Areas 5,6	5.7	6.8	3.6	3.6	3.5	4.1	4.1	4.4	1.1	1.2	5.4	5.3	1.4	0.3	4.2	4.8
Area 16(N. of BNP)	0.3	0.2	0.4	0.3	0.4	0.3	0.5	0.4	0.5	0.5	0.2	0.1	0.7	1.8	0.3	0.3
Area 17(S. of BNP)	4.6	6.4	4.8	5.4	4.2	6.8	2.0	2.2	9.1	10.3	3.8	4.2	2.0	2.0	4.7	6.0
Other	1.7	1.9	1.2	1.6	2.4	2.5	0.5	1.0	1.6	2.6	1.0	1.3	0.0	0.0	1.5	1.8
Area 20	0.2	0.2	0.3	0.2	0.1	0.5	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.2	0.2
Area 21	0.1	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.1
Area 22	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.7	3.6	0.0	0.1
Area 23	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.1	1.1	0.7	0.2	0.1	0.0	0.0	0.2	0.1
Area 24	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0
Total Trips	9,244		5,199		5,071		3,473		3,142		2,647		147		28,923	
Total Catch (no.)		133,608		60,685		50,949		29,442		43,196		67,246		1,120		388,246

Table 5.—Percentage of recreational fishing trips (n = 28,923) reported using BNP statistical fishing areas by year. Annual sample sizes are shown in Figure 1. Areas 20–24 were added after BNP boundary expansion in 1993.

Fishing zones	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Area 1	2.0	2.9	6.8	3.2	1.6	2.7	4.5	4.0	4.0	2.2	2.1	1.5	0.7	1.1	0.2	0.2
Area 2	5.2	4.7	3.4	6.5	8.3	3.6	4.6	9.2	9.5	6.7	7.7	6.3	5.1	4.5	3.6	4.3
Area 3	5.9	2.7	2.1	3.0	3.0	1.9	2.3	3.5	2.4	2.7	2.5	2.6	2.8	2.0	0.7	1.0
Area 4	14.8	14.3	11.9	17.2	20.8	10.1	12.9	16.1	15.5	12.4	14.8	13.5	5.9	7.4	7.3	3.5
Area 5	33.0	26.0	18.0	20.7	34.3	35.9	45.4	36.2	47.4	37.2	41.1	36.0	43.4	43.8	45.8	46.0
Area 6	24.5	34.4	37.9	29.1	14.5	24.5	13.3	15.2	8.8	24.1	24.2	22.3	22.8	25.1	24.3	34.4
Areas 1,2	0.7	0.7	0.6	0.5	0.6	0.6	1.2	0.7	0.3	0.1	0.3	1.1	0.3	0.0	0.1	0.4
Areas 1,3	0.3	0.1	0.3	0.1	0.1	0.6	0.9	0.3	0.0	0.1	0.3	0.1	0.3	0.0	0.0	0.0
Areas 2,4	0.5	0.6	0.6	0.4	0.9	0.6	1.2	1.8	1.2	0.6	0.2	1.1	0.8	0.8	0.6	0.6
Areas 3,4	1.4	0.6	1.2	0.7	0.7	0.7	0.7	0.8	0.5	0.2	0.2	0.4	0.4	0.3	0.1	0.4
Areas 1,2,3,4	1.3	0.8	0.2	0.6	0.2	0.3	0.4	0.1	0.3	0.1	0.0	0.3	0.1	0.1	0.0	0.0
Areas 3,5	0.7	0.2	0.2	0.3	0.2	0.4	0.7	0.3	1.0	0.4	0.0	0.5	0.1	0.0	0.1	0.0
Areas 4,5	2.0	1.7	1.4	2.1	3.1	2.2	4.0	2.9	0.9	1.5	0.2	2.9	2.3	2.1	2.7	1.2
Areas 3,4,5	1.0	0.2	0.1	0.1	0.2	0.5	0.9	0.2	0.0	0.2	0.0	0.2	0.1	0.1	0.0	0.4
Areas 5,6	4.8	3.6	4.4	7.9	3.9	5.6	3.8	3.7	0.5	1.3	0.2	3.5	4.5	5.0	4.8	2.5
Area 16(N. of BNP)	0.1	0.7	0.6	0.6	0.0	0.8	0.3	0.0	0.2	0.1	0.1	0.3	0.1	0.1	0.2	0.2
Area 17(S. of BNP)	1.1	4.2	6.5	4.8	4.8	5.2	2.0	4.1	6.6	7.7	4.3	4.6	8.9	6.1	7.0	3.1
Other	0.9	1.5	3.9	2.1	2.9	3.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Area 20								0.4	0.2	0.5	0.6	1.5	0.3	0.1	0.0	0.0
Area 21								0.2	0.3	0.3	0.6	0.3	0.1	0.6	0.1	0.0
Area 22								0.2	0.0	0.1	0.2	0.1	0.1	0.3	0.0	0.0
Area 23								0.1	0.2	0.5	0.3	1.1	0.6	0.4	2.0	1.6
Area 24								0.0	0.2	0.7	0.2	0.0	0.1	0.0	0.1	0.2

Average annual fish size and total trip landings were compared for common species landed by both angling and spearfishing. Mean annual fish weight was significantly greater from spearfishing trips for black grouper, red grouper, and gray snapper ($p < 0.01$, t-test), but not significantly different for hogfish, Nassau grouper, and mutton snapper ($p > 0.05$, Table 7). Mean annual landing per trip were significantly greater for spearfishing trips than for hook and line trips for black grouper, Nassau grouper, and red grouper ($p < 0.01$, t-test), while no significant differences were found for hogfish, gray snapper, or mutton snapper ($p > 0.05$, Table 7). Thus, although average gray snapper size was larger for spearfishing trips, there was no significant difference in weight per trip because anglers landed more fish per trip. In contrast, spearfishing landed significantly more Nassau grouper per trip than angling ($p > 0.01$). In summary, although spearfishing targeted some of the same species as anglers, the total landings from spearfishing was only a small portion of the total landings from hook and line fishing.

Comparison of Fishery-Dependent and Independent Trends

The SEFSC has conducted fishery-independent, visual sampling of fishes

Table 6.—Species landings composition by year for 3,473 recreational spearfishing fishing trips in BNP. Several taxa were reported only at the family level in 1976 and 1977.

	Scientific name	Common name	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	All years
1	*Acanthocybium solandri*	Wahoo		1															1
2	*Acanthurus bahianus*	Ocean surgeon						1	1										2
3	*Acanthurus coeruleus*	Blue tang												1					1
4	*Albula vulpes*	Bonefish		1															1
5	*Alectis ciliaris*	African pompano						1		1		1							3
6	*Anisotremus surinamensis*	Black margate			2	10	6	28	23	29	3	8	8	9	6	3	7	5	147
7	*Anisotremus virginicus*	Porkfish				1	2	4	6	1			3			1			18
8	*Archosargus probatocephalus*	Sheepshead		11	5														16
9	*Archosargus rhomboidalis*	Sea bream						4											4
10	*Aulostomus maculatus*	Trumpetfish							2										2
11	*Balistes capriscus*	Gray triggerfish					2	1	2						1				6
12	*Balistes vetula*	Queen triggerfish					1	2		1									4
13	*Bodianus rufus*	Spanish hogfish			1	2		1	3	3			2		3				15
14	*Calamus arctifrons*	Grass porgy								1									1
15	*Calamus bajonado*	Jolthead porgy	2	18	33	15	1	1	8	13		1	1				1	1	95
16	*Calamus calamus*	Saucereye porgy					4	1				5	1				1		12
17	*Cantherhines pullus*	Orangespotted filefish					1		1										2
18	*Canthidermis sufflamen*	Ocean triggerfish				6	1	7	1	4			3	3	2	1	4		32
19	*Caranx bartholomaei*	Yellow jack				3	10	39	42	18	2	6	7	11	6	3	17	11	175
20	*Caranx crysos*	Blue runner	9	2	4	12	6	9	2	8	1	2	4	2	3	1	1	1	67
21	*Caranx hippos*	Crevalle jack				2	3	2	9	4									20
22	*Caranx latus*	Horse-eye jack						1	1										2
23	*Caranx ruber*	Bar jack			1	4	2	8	5	1		2	1	4	4		1	1	34
24	*Caranx* spp.	Unidentified jack	7	53	45					12	1	1						1	120
25	*Carcharhinus* spp.	Unidentified shark	2	1		1			2			1			1				8
26	*Centropomus ensiferus*	Swordspine snook					1												1
27	*Centropomus undecimalis*	Common snook						1											1
28	*Chaetodiperus faber*	Atlantic spadefish				2	14	4	3	4	1	2	4		3				37
29	*Coryphaena hippurus*	Dolphin	1	1	8	1			6	7			1	5					30
30	*Dasyatis* spp.	Unidentified stingray				1		1											2
31	*Diplectrum formosum*	Sand perch					2												2
32	*Elagatis bipinnulata*	Rainbow runner					2	1		1									4
33	*Epinephelus adscensionis*	Rock hind			2	3	3	2	4	3			4					2	23
34	*Epinephelus cruentatus*	Graysby				5	9	9	9	7	1		1	1					42
35	*Epinephelus flavolimbatus*	Yellowedge grouper								8									8
36	*Epinephelus fulvus*	Coney				1			2										3
37	*Epinephelus guttatus*	Red hind			1	21	6	11	15	9	2	3			1				69
38	*Epinephelus inermis*	Marbled grouper								1									1
39	*Epinephelus itajara*	Jewfish				2		2	1	1									6
40	*Epinephelus morio*	Red grouper			7	135	76	181	128	200	15	38	12	11	22	14	7	5	851
41	*Epinephelus striatus*	Nassau grouper			14	310	187	158	82	29	3	10	5	2	2	3	3	1	809
42	*Gerres cinereus*	Yellowfin mojarra						1											1
43	*Ginglymostoma cirratum*	Nurse shark			2		2		1	3									8
44	*Gymnothorax* spp.	Unidentified moray				2	2	1											5
45	*Haemulon album*	Margate			7	14	16	5	14	6			5	2		1	3	2	75
46	*Haemulon carbonarium*	Caesar grunt					1					1		1	2		1	2	8
47	*Haemulon flavolineatum*	French grunt				2			3										5
48	*Haemulon macrostomum*	Spanish grunt				1	1	1	5	4	1	1	2			1	2	1	20
49	*Haemulon parrai*	Sailor's choice						3						1			1		5
50	*Haemulon plumieri*	White grunt	1		7	47	22	24	32	86		13	16	10	19	1	2	29	309
51	*Haemulon sciurus*	Bluestriped grunt	1		14	34	47	32	25	26	2		9		5	6		1	202
52	*Haemulon* spp.	Unidentified grunt	69	108	41	1	20		1	36		1						0	277
53	*Haemulon striatum*	Striped grunt					1												1
54	*Halichoeres bivittatus*	Slippery dick											11						11
55	*Halichoeres radiatus*	Puddingwife								1									1
56	*Halichoeres* spp.	Unidentified wrasse								1									1
57	*Holacanthus ciliaris*	Queen angelfish								2									2
58	*Holocentrus adscensionis*	Squirrelfish												1					1
59	*Kyphosus incisor*	Yellow chub								1				1				1	3
60	*Kyphosus sectatrix*	Bermuda chub				2	5	9	3	4	2	2		1				2	30
61	*Kyphosus* spp.	Unidentified chub												1			2		3
62	*Lachnolaimus maximus*	Hogfish	452	1,562	1,704	1,334	1,068	1,660	1,661	2,022	127	353	284	237	199	216	304	103	13,286
63	*Lactophrys* spp.	Unidentified boxfish					1	1		2									4
64	*Lagodon rhomboides*	Pinfish								3									3
65	*Lutjanus analis*	Mutton snapper			1	69	57	63	58	52	3	11	7	3	5	15	12	8	364
66	*Lutjanus apodus*	Schoolmaster				26	13	45	70	50	2	2	9	11	7	3	8	6	252
67	*Lutjanus buccanella*	Blackfin snapper								1									1
68	*Lutjanus cyanopterus*	Cubera snapper				11		3	1								1		16
69	*Lutjanus griseus*	Gray snapper	3		26	206	182	309	248	201	15	74	43	13	34	11	52	15	1,432
70	*Lutjanus jocu*	Dog snapper				8	14	24	7	4	1	2			1	1	1		63
71	*Lutjanus mahogoni*	Mahogany snapper					1	1	1	1			1	3		1		1	10
72	*Lutjanus* spp.	Unidentifed snapper	128	306	251		5	2	14	1		2				2	7		718
73	*Lutjanus synagris*	Lane snapper				4	2	2	5	6				1	1				21
74	*Lutjanus vivanus*	Silk snapper							3										3
75	*Malacanthus plumieri*	Sand tilefish						1	1										2
76	*Mulloidichthys martinicus*	Yellow goatfish						2								1		1	4
77	*Mycteroperca bonaci*	Black grouper			10	219	80	223	97	69	12	14	5	6	7	10	8	5	765
78	*Mycteroperca interstitialis*	Yellowmouth grouper			1	2	1	6		2					2				14

continued

Table 6.—(Continued).

	Scientific name	Common name	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	All years
79	*Mycteroperca microlepis*	Gag			8	8	3	15	24	8	1	4	1	3	1		1		77
80	*Mycteroperca phenax*	Scamp				2	1		3										6
81	*Mycteroperca venenosa*	Yellowfin grouper			4	7	4	1	14										30
82	*Ocyurus chrysurus*	Yellowtail snapper				12	35	7	34	16		22	3	5	29	10	5		178
83	*Panulirus argus*	Caribbean spiny lobster	24	354	411	432	25	190	803	182	35	132	27	7			1		2,623
84	*Panulirus guttatus*	Spotted lobster			1	3		1	5										10
85	*Pomacanthus arcuatus*	Gray angelfish								2									2
86	*Priacanthus arenatus*	Bigeye		9	29		1		1					1					41
87	*Prionotus* spp.	Unidentified searobin							1										1
88	*Rhomboplites aurorubens*	Vermilion snapper							11										11
89	*Sarda sarda*	Atlantic bonito		1	1														2
90	*Scarus guacamaia*	Rainbow parrotfish					1			1						1		2	5
91	*Scomberomorus cavalla*	King mackerel								1						1			2
92	*Scomberomorus maculatus*	Spanish mackerel			1	3	1	7	6	2			1						21
93	*Scomberomorus regalis*	Cero mackerel				10	8	4	16	7			1	1	2	1	1	2	53
94	*Scyllarides aequinoctialis*	Shovel-nosed lobster						1								12			13
95	*Seriola dumerili*	Greater amberjack			1	31	9	3	4	3	1	1	5	1					59
96	*Sphoeroides* spp.	Unidentified puffer					1												1
97	*Sphyraena barracuda*	Great barracuda	9	17	10	11	9	16	27	31	1	4	1	6	3		14	2	161
98	*Sphyrna tiburo*	Bonnethead								1									1
99	*Strombus gigas*	Queen conch	5	127	137	203	61	105	204	129	27	20							1,018
100	*Thunnus* spp.	Unidentified tuna	1	3	8					1		1							14
101	*Trachinotus falcatus*	Permit						3	3	2	1		1		3		3		16
102	*Tylosurus crocodilus*	Houndfish															5		5
103	N.A.	Unidentified bigeye								1									1
104	N.A.	Unidentifed filefish								1									1
105	N.A.	Unidentifed catfish			1														1
106	N.A.	Unidentified grouper	201	665	738	0	3	24	5	161	3	10	1	1		0			1,812
107	N.A.	Unidentified anglefish				4	7	2	16						4				33
108	N.A.	Unidentified lefteye flounder								3	1								4
109	N.A.	Unidentified fishes	16	76	34		1	4	2	6									139
110	N.A.	Unidentified parrotfish			2	1	10	26	10	8	2	1	2		2	7			71
Totals			931	3,316	3,573	3,246	2,060	3,307	3,797	3,516	266	751	492	366	380	327	476	211	27,015
No. of interviews			127	385	463	409	336	381	491	362	38	106	94	68	61	54	61	37	3,473
Avg. landed/trip			7.33	8.61	7.72	7.94	6.13	8.68	7.73	9.71	7.00	7.08	5.23	5.38	6.23	6.06	7.80	5.70	7.78

Table 7.—Comparison of mean annual fish weight and mean total trip landings for six species from spearfishing and hook & line trips from 1978–1991 (* = $p < 0.05$, ** = $p < 0.01$, t-test, $n = 14$).

Species	Spearfishing trips Mean (range)	Hook and line trips Mean (range)
Hogfish		
Kg/fish	0.83 (0.57–1.10)	0.77 (0.60–1.00)
Kg/trip	3.04 (1.77–4.58)	0.08 (0.02–0.14)
Black grouper		
Kg/fish**	3.83 (1.95–5.94)	2.15 (1.10–4.88)
Kg/trip**	0.71 (0.13–1.78)	0.05 (0.02–0.12)
Nassau grouper		
Kg/fish	1.85 (0.07–4.65)	1.37 (0.74–2.60)
Kg/trip	0.28 (0.00–1.23)	0.08 (0.00–0.11)
Red grouper		
Kg/fish**	1.38 (0.91–2.31)	1.00 (0.68–1.21)
Kg/trip**	0.35 (0.02–0.61)	0.08 (0.02–0.19)
Mutton snapper		
Kg/fish	1.32 (0.76–1.99)	1.09 (0.58–1.85)
Kg/trip	0.16 (0.00–0.31)	0.12 (0.02–0.19)
Gray snapper		
Kg/fish**	0.64 (0.43–1.06)	0.27 (0.23–0.40)
Kg/trip	0.31 (0.03–0.57)	0.28 (0.02–0.49)

on inshore patch reefs and offshore bank reefs in BNP statistical Areas 5 and 23 (Fig. 1) since July 1988. Ault et al. (1998) showed that underwater visual size estimates of fishes corresponded well to sizes in headboat landings in the Florida Keys. Abundance indexes for the 10 most commonly landed fishes were compared between BNP creel census data (mean landings per trip) and SEFSC visual census data (mean abundance per sample) for combined statistical Areas 5 and 23 for July 1988–July 1991 (Fig. 9). Trends in the two indexes were highly similar for white grunt and great barracuda and somewhat similar for seven of the remaining fishes. The blue runner, *Caranx crysos*, exhibited the greatest difference, most likely because it was caught in many habitats while visual data were restricted to reefs. Despite having only 4 years of corresponding data (July 1988–July 1991), the two indices showed good correspondence between fishery-independent visual sample abundance and fishery-dependent creel sample abundance for reef fishes. A longer data time-series is needed, however, to identify meaningful trends in the relationship between recreational harvest and visual sample abundances.

Annual Mean Landings Rates

Annual mean catch (CPUE) and landings (LPUE) rates for eight commonly landed fishes were calculated in terms of fish per angler-hour for anglers (Fig. 10). Although variable, the annual rate trends for these eight species indicated a slight decreasing trend. The difference between CPUE and LPUE is the estimated bycatch. Dolphin and jolthead porgy had low release rates while grunts had the highest release rates. The divergence between CPUE and LPUE beginning in 1985 and 1990 for gray snapper, yellowtail snapper, and other snappers is most likely the result of increased releases as the result of new minimum size requirements discussed earlier.

Landings trends were further analyzed for species having 12 or more years of reported data on the basis of total number of fish landed per 100 trips (Table 8, Fig. 11). Trend curves were fitted to the data using linear, logarithmic, or exponential curves, as appropriate. Data from 1976 to 1978 were dropped from plotted trends for some species (Fig. 11) because it was clear that these data had been combined at the family level. Overall, the number

of fish landed per trip declined (Fig. 11), although landings declined more rapidly for some species than others. Landings declines for jolthead porgy and Nassau grouper were especially sharp. Size limits for gray snapper and yellowtail snapper established in 1985, probably accounted for reduced landings for those species.

Discussion

The Biscayne National Park recreational creel survey provides valuable data for monitoring marine resource trends and for better understanding impacts of recreational fishing on marine resources. Recreational fishing in BNP is intense because of its unique location near the large urban area of Miami. This study provides one of the most detailed examinations of recreational fishing in such a subtropical marine environment. Creel data show landings of over 170 species from a variety of habitats and are especially representative of weekend recreational fishing since 91% of the samples were collected on weekends. The data potentially have some bias because sampling was nonrandomly distributed over space and time. The validity of extrapolating results to weekday fishing is uncertain because of low sample coverage during weekdays. The relative contribution of recreational lobster fishing to total interviews is probably inflated because of concentrated sampling during opening days of the spiny lobster fishing season and 2 day sport season. The fact that sampling was highly concentrated at two access sites within BNP suggests that the data might not reflect use from other locations. Presumably, fishermen landing in BNP are aware that they have a high chance of being checked by park personnel and may be more conscientious of observing fishing regulations.

The classification of angler and diving party types provides some insights into recreational fishing. The fishing party type showing a high level of species preference was spiny lobster divers (89% of parties, Table 2). The remaining party classifications showed no preference or very generalized species preferences. Angling party classifications broadly overlapped in terms

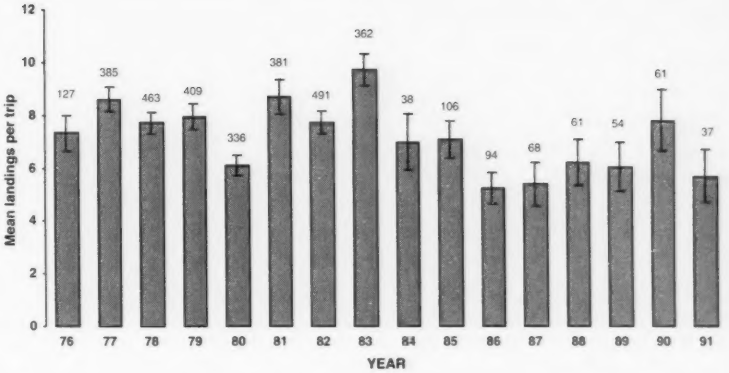

Figure 6.—Annual mean number of fish landed per spearfishing trip (± SE). Numbers show sample size.

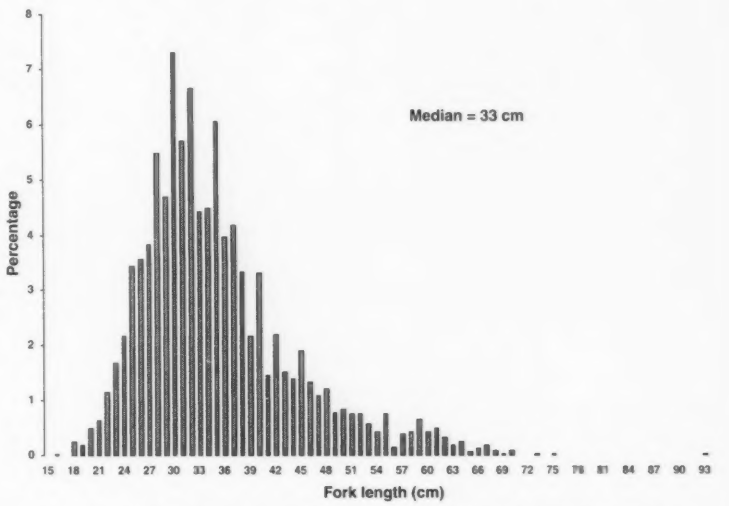

Figure 7.—Length-frequency distribution of speared hogfish sampled in creel surveys (mean = 35.06 cm FL, n = 3,323).

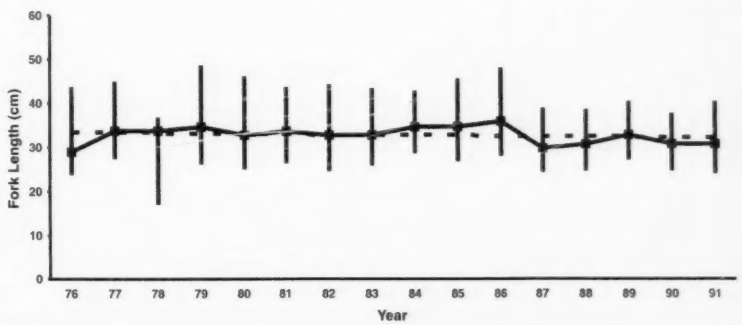

Figure 8.—Annual sizes of *Lachnolaimus maximus* landed from spearfishing trips. The solid line shows median sizes, vertical lines show ± SE around central means, and the dotted line shows the linear trend.

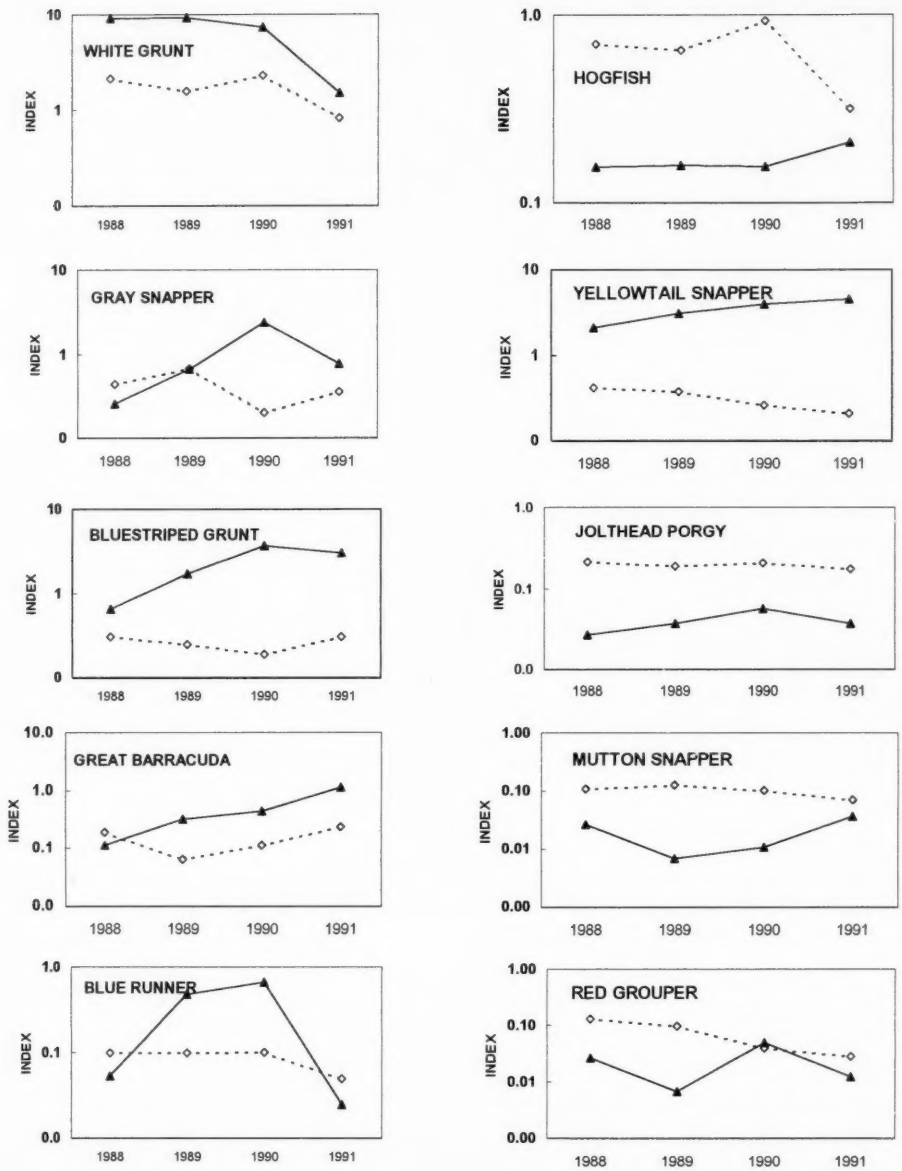

Figure 9.—Comparison of trends in annual mean abundance of landings per trip (diamonds, BNP Creel Census interviews) and mean observed abundance (triangles, SEFSC visual census samples) for the ten most commonly landed fishes from statistical areas 5 and 23 from July 1988 through July 1991.

of species landed and were not highly differentiated by levels of experience or emphasis on recreation or catching food. Only five taxa accounted for more that 50% of landings: white grunt, spiny lobster, gray snapper, unidentified grunts, and dolphin. Angling parties primarily interested in catching food accounted for about 20% of trip interviews and had about twice the landing per trip (mean = 19.5) than skilled recreational anglers (9.6), lob-

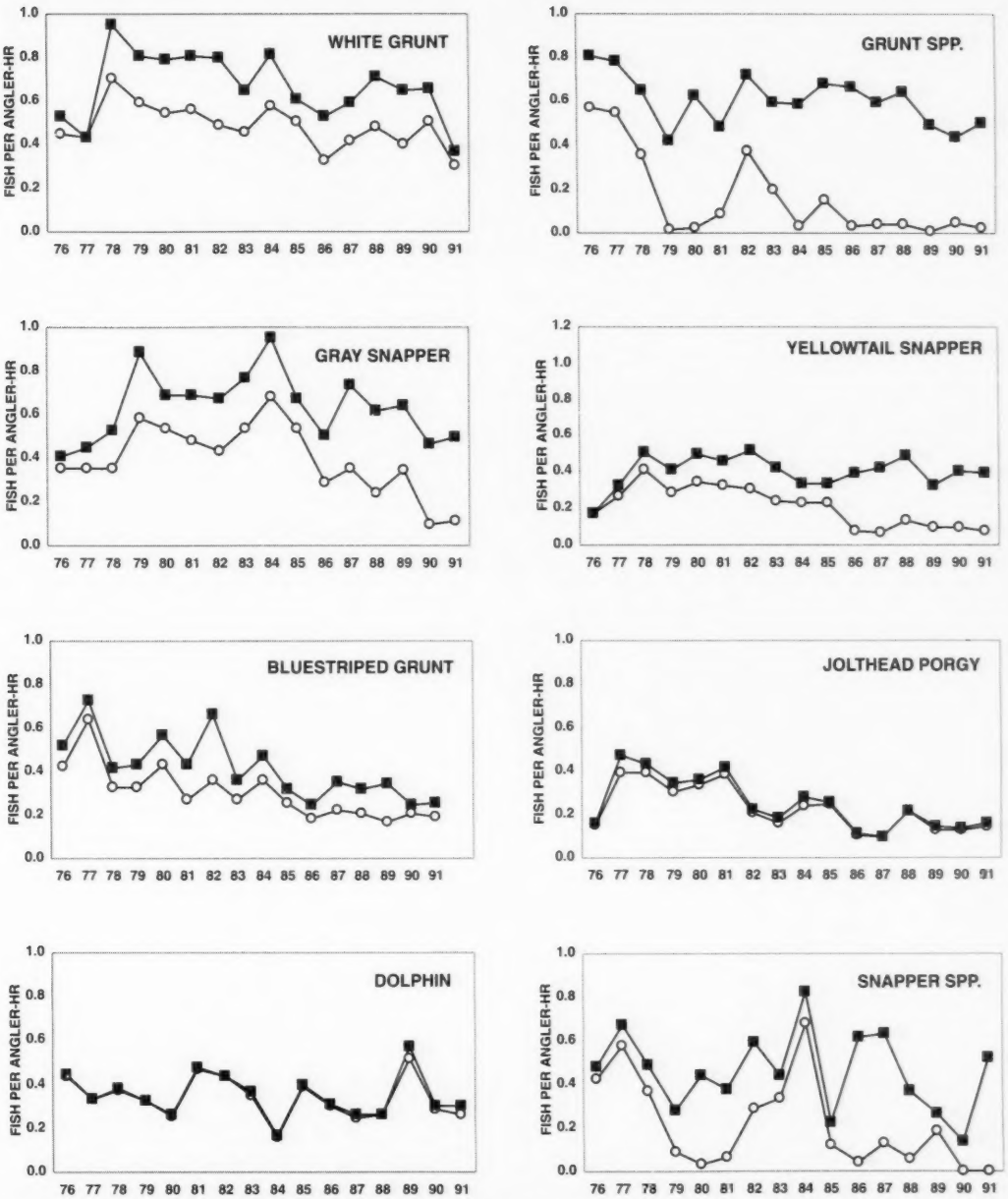

Figure 10.—Comparison of mean annual landing rates (circles) and catch rates (squares) reported in Biscayne National Park creel census interviews.

ster divers (8.2) and spearfishermen (7.8). Skilled parties, however, accounted for the greatest percentage (34%) of the total fishing trips.

Spearfishing data were closely examined because few quantitative studies exist and spearfishing is a frequent topic of management and angler concern due to its selectivity (Murdock, 1957; Long, 1957). Spearfishing was a small component of the overall recreational fishery. It accounted for 12.0%

Table 8.—Annual CPUE index (no. landed/100 interviews) by species with 12 or more years of data. Underline shows data for species after minimum size limits were implemented. Data for some species were available only at the family level in 1976 and 1977.

Species	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
African pompano			0.031	0.198	0.038	0.042	0.195	0.133	0.345	0.594	0.403		0.141		0.241	1.174
Atlantic bonito	5.000	2.651	2.265	1.256	0.798	2.020	0.781	0.433		0.297	1.610			0.425		0.587
Ballyhoo	0.789	1.363	0.944	3.802	13.835	15.320	31.809	14.481	7.759	4.900	3.382	1.644		1.558		
Bar jack	0.197	0.076	0.220	0.264	0.342	1.641	0.753	0.666	0.172	0.520	0.644	0.774	0.986	0.142	0.602	0.196
Bermuda chub			0.157	1.620	4.257	2.315	2.565	2.130	2.241	1.633	1.369	1.547			0.602	1.370
Bigeye	3.421	9.353	6.889	0.529	1.862	3.367	0.753	0.233		0.445	0.725	4.642	0.282	0.142	0.361	0.196
Black grouper	0.132		1.101	11.901	6.727	12.668	6.189	4.028	6.207	4.677	1.691	2.418	2.394	4.108	1.566	1.370
Black margate			0.063	0.694	0.456	1.599	0.976	1.032	0.690	1.782	1.127	1.257	2.958	1.133	2.530	2.153
Bluerunner	8.618	4.354	3.555	7.537	11.631	17.340	18.233	22.204	7.931	12.027	23.752	27.369	25.211	16.997	14.337	8.415
Bluestriped grunt	29.276	3.900	24.190	50.182	47.777	35.269	67.076	38.349	53.276	30.809	20.290	37.814	37.183	27.620	29.398	26.223
Cero mackerel			0.252	6.512	6.613	6.987	5.074	3.628	2.931	2.153	4.187	6.867	3.662	1.558	3.133	1.174
Crevalle jack				3.537	0.988	0.463	3.541	2.297	0.172	0.223	0.403	1.354	1.690	0.425	0.482	
Dolphin	113.224	53.692	57.314	54.612	26.416	76.010	68.637	57.490	7.241	63.697	55.153	30.754	43.803	128.187	55.060	89.041
Gag	0.132		0.692	4.066	1.710	1.978	4.572	3.129	2.414	1.039	0.644	2.031	1.831	0.425	0.361	2.153
Gray snapper	2.566		7.644	145.025	151.957	150.589	114.943	169.740	196.034	138.976	61.514	88.878	58.310	100.567	29.277	31.703
Gray triggerfish				0.264	1.064	0.421	3.318	2.397	1.207	1.114	0.242	1.547	2.113	0.850	0.843	3.327
Graysby			0.283	1.587	2.889	4.251	2.816	2.830	1.379	3.489	1.369	2.805	7.465	3.116	7.108	1.370
Great barracuda	30.921	19.614	15.697	25.587	27.708	14.731	22.693	17.144	11.724	14.180	19.726	23.694	27.324	11.331	19.639	19.765
Greater amberjack			0.063	2.182	1.596	2.146	1.394	0.566	0.172	0.520	0.966	1.547	0.141	0.850	0.120	1.566
Grouper spp.	73.684	88.792	64.360	1.785	0.304	2.399	1.589	15.413	3.448	5.419	0.483	0.967	2.394			
Grunt spp.	257.105	254.714	139.352	2.876	6.575	12.710	15.054	73.136	6.724	21.381	3.623	8.801	4.648	1.841	19.518	2.153
Hogfish	44.145	67.134	62.535	48.661	48.727	84.596	49.596	76.498	36.897	38.827	31.723	29.691	38.169	36.686	48.554	23.092
Jack spp.	8.618	14.464	10.506	0.298	0.076	1.641	0.502	1.764	0.517	1.707	0.242	0.774				0.196
Jolthead porgy	13.816	50.322	77.477	62.744	46.636	38.805	22.693	20.406	36.724	30.586	4.911	7.544	18.732	13.881	15.904	13.894
King mackerel			0.157	1.421	1.026	1.178	0.836	1.032	0.517	0.891	0.403	1.257	0.563	0.850	2.169	0.783
Lane snapper			1.919	5.653	14.785	9.428	6.802	6.059	1.034	6.013	2.174	5.513	11.127	3.824	1.205	0.783
Margate			0.535	2.017	1.900	1.641	5.018	1.431	0.517	1.633	3.623	2.998	0.845	1.133	2.410	0.391
Mutton snapper			1.258	16.331	16.268	14.689	9.256	13.316	14.138	5.568	6.924	23.114	11.127	11.331	10.723	6.654
Nassau grouper	0.461		0.912	17.719	15.317	9.470	6.050	2.130	2.759	3.935	1.208	1.161	1.831	1.983	0.602	0.196
Nurse shark			0.063	0.231	0.152	0.210	0.195	0.566	0.345	0.074		0.387	0.141	0.283		0.391
Ocean triggerfsh			0.283	4.595	5.549	4.503	0.335	2.430	0.517	2.821	2.736	2.031	5.211	2.408	4.096	0.587
Parrotfish spp.			0.377	0.694	0.988	1.473	1.645	2.097	0.690	0.520	0.966	1.644	2.113	2.266	0.120	
Pinfish	0.132		3.209	17.157	18.092	12.037	19.849	30.260	8.448	2.598	7.407	6.963	1.690	5.382	1.325	
Porkfish				0.463	1.862	1.726	0.613	2.097	0.345	0.520	0.644	1.354	0.423	0.992	1.566	0.783
Queen triggerfsh			0.031	0.364	0.532	0.758	0.251	0.399		0.668	0.081	0.677	0.141	0.992	0.964	0.783
Red grouper	0.461		1.730	18.876	10.718	19.192	9.060	22.437	15.172	16.110	4.348	8.414	9.577	10.765	3.494	2.935
Red hind			0.440	4.826	2.433	3.030	5.185	1.132	2.414	1.188	0.644	1.161	2.676	0.567	0.361	6.849
Rock hind			0.252	1.554	0.608	0.631	2.147	0.699		0.891	0.403	0.097	0.704	0.850	0.361	0.391
Sailfish	0.526	0.227	0.472	0.231	0.076	0.210	0.167	0.300		0.371	0.242	0.193	0.141	0.142	0.120	0.783
Sailors choice			0.975	2.215	2.585	1.768	1.756	3.262	1.552	1.188	1.771	4.836	17.042	8.215	3.133	2.935
Sand perch	5.658	3.218	15.351	9.289	8.894	6.818	2.844	2.264	11.897	0.520	2.335	2.418	2.113	0.850	0.843	0.783
Sand tilefish			0.031	1.124	1.558	1.305	1.728	0.599		0.371	0.081	0.774	0.845	0.567	0.241	
Saucereye porgy				0.033	7.678	23.106	2.063	2.430	0.517	11.359	4.911	1.934	1.268	2.408	6.386	0.196
Schoolmaster			0.755	2.380	3.801	4.293	3.513	3.296	0.862	2.004	2.254	5.513	4.507	7.224	3.614	2.935
Seatrout	0.658	4.354	9.059	4.132	4.485	1.473	13.633	7.956	6.897	1.633	0.644	0.580	0.141	1.133		
Shark spp.	1.579	0.492	0.535	0.198	0.190	0.295	0.223	0.033		0.297		0.387	0.423	0.142	0.120	
Snapper spp.	195.000	242.030	157.156	1.223	1.558	1.726	2.648	4.860	10.000	4.974	0.483	3.095	0.704	1.133	0.843	
Spadefish				0.066	0.532	0.210	0.139	0.233	0.172	0.148	0.322	0.097	0.986		0.120	0.391
Spanish grunt				0.099	0.076	0.800	0.446	0.533	0.172	0.148	0.242	0.290	0.704	0.283	0.241	0.196
Spanish mackerel			0.315	0.992	0.760	1.263	3.122	0.466	0.172	0.297	4.267	1.257	0.141	0.142	0.120	1.370
Spiny lobster	79.737	111.056	80.466	73.190	114.253	76.389	97.909	44.041	131.552	37.416	113.768	113.636	155.915	170.538	233.494	203.718
Wahoo	0.263	0.530	0.252	0.793	0.532	0.547	0.502	0.566	0.517	0.223	0.886	0.580	1.268	0.283	0.723	1.957
White grunt	36.842	2.272	71.186	221.521	205.853	224.747	208.754	129.561	137.241	171.641	106.522	137.524	161.127	129.320	166.506	69.667
Yellow jack			0.031	0.298	0.950	4.798	2.258	2.264	1.034	1.707	1.530	4.642	5.352	2.691	5.542	3.914
Yellowtail snapper	0.329		10.727	71.273	94.033	80.724	83.301	77.164	62.586	58.203	14.010	17.118	34.789	25.637	25.542	18.004

of all recreational fishing trip interviews, 10.3% of the total number of landings, but only 7.6% of the total number of organisms caught in BNP. No data exist, however, to assess cryptic mortality of speared organisms that escape capture. The fact that fishing trips were randomly selected for interviews suggests that the relative proportion of angler to spearfishing trips is valid.

Spearfishing was highly selective for hogfish which accounted for almost half (49%) of spearfishing landings. The data suggest, however, that there is relatively little competition for hogfish between anglers and spearfishermen. Anglers rarely mentioned hogfish as preferred target species (Table 2). Many anglers consider hogfish difficult to hook and only 15.7% of hogfish were landed by angling. After hogfish, spearfishing most commonly targeted various grouper and snapper. While the average size of some species of fish caught by spearfishing was larger than that caught by angling (e.g. gray snapper, red grouper, black grouper), there was no significant size difference for other species (e.g. white grunt, hogfish, Nassau grouper). Even though spearfishing landed larger fish for some species, anglers tended to land more fish because they made more trips.

Spearfishing can cause behavioral changes and other impacts that were not addressed by this study. Some species, for example, are known to avoid divers and areas where spearfishing is practiced (Randall, 1982). This avoidance can impact recreational diving, education, tourism, and other nonextrac-

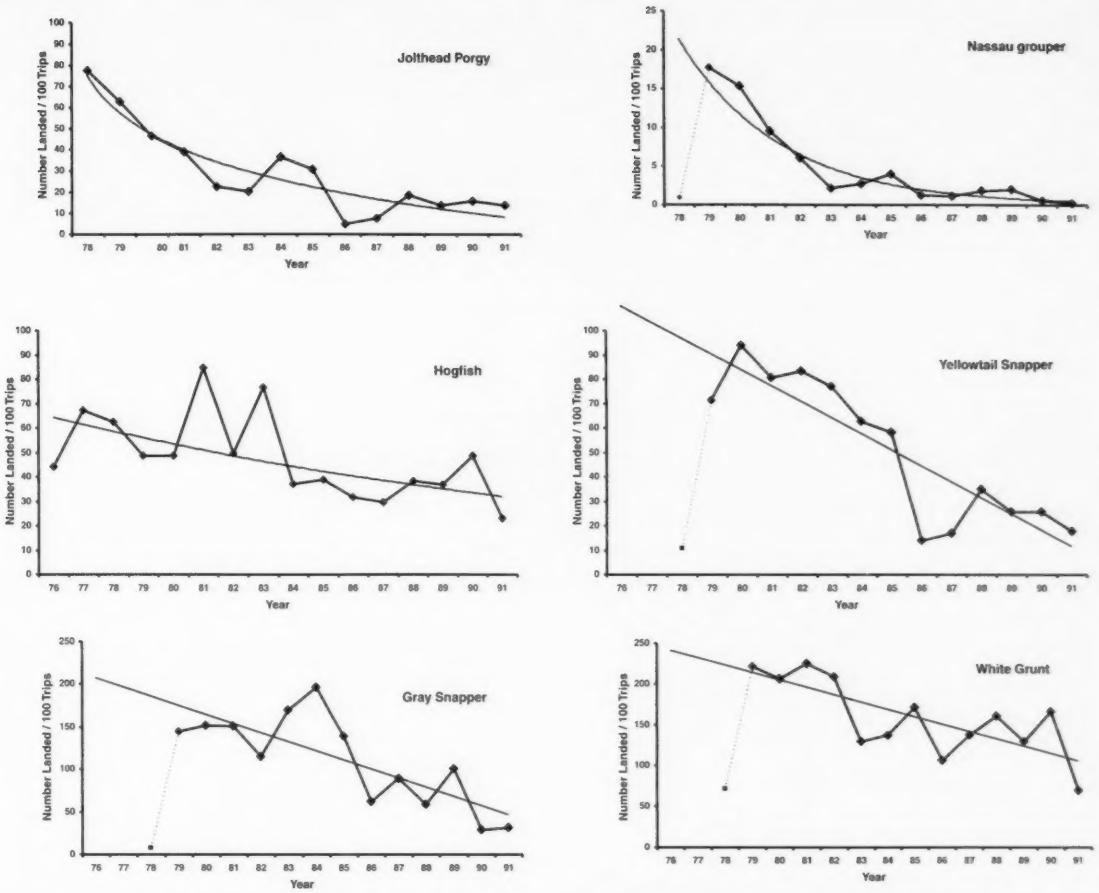

Figure 11.—Trends in total number of fish landed per 100 trips from BNP interviews. Fitted curves were linear for yellowtail snapper, gray snapper, and white grunt; exponential for hogfish and Nassau grouper; and logarithmic for jolthead porgy. Data for some species were excluded from analysis for 1976–78 because they were reported at the family level.

tive uses. Simply moving fish around is not a fishery problem, however, unless fish populations are excluded from essential habitat for foraging, shelter, or reproduction (Bohnsack, 1982).

Unlike earlier studies of BNP (Tilmant et al., 1979; Tilmant, 1981; Tilmant and Stone[1]), this study showed declining CPUE for some species. The continuous CPUE decline of jolthead porgy, for example, suggests that it may be particularly vulnerable to increased exploitation. Whether the observed landings declines represent diminished resources or diminished shares caused by increased usage cannot be precisely determined from available data without some measure of total effort. Over the study time period, the estimated population of Miami-Dade County increased 32.3% from 1,482,300 in 1976 to 1,961,700 in 1991 (Floyd, 1997). An assumption that recreational fishing effort is directly proportional to the total population would suggest that total recreational fishing effort also increased by 32%.

Although observed drops in mean annual number of fish landed per angler trip in 1985–86 and in 1990–91 were most likely the short-term result of numerous new minimum size limits enacted in Florida in 1985 and 1990, respectively, the long-term impacts of these conservation efforts could not be assessed because of disruptions to fishing and the environment caused by Hurricane Andrew. More recent regulations such as new minimum size and bag limits also are likely to impact recreational fishing in Biscayne National Park. The recreational creel survey has obvious importance for resource monitoring and would be enhanced if data can be collected on total fishing effort.

Acknowledgments

This study was funded by Sub-Agreement IA-5250-2-9501/2 to Interagency Agreement 1A-5000-8-8011 between the National Park Service and the NMFS Southeast Fisheries Science Center. We

thank Richard Curry of the Biscayne National Park for contributions and assistance provided during this study. Thomas Schmidt Everglades National Park, and Jim Tilmant, NPS, provided comments and reviewed of the manuscript.

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Preliminary Analysis of the Feasibility of Transferring New Longline Technology to Small Artisanal Vessels off Northeastern Brazil

F. H. V. HAZIN, M. K. BROADHURST, and H. G. HAZIN

Introduction

Fishing communities along the northeast coast of Brazil rely heavily on inshore stocks of several commercially important species and have adopted a range of simple fishing methods for their exploitation. Most fishing occurs within 20 km of the coast using small simple wooden vessels (6–12 m), powered by 3- or 4-cylinder diesel motors, and includes handlining for benthic species of fish (i.e. snappers, *Lutjanus* spp.; weakfish, *Cynoscion* spp.; and groupers, *Mycteroperca* spp.) and more commonly, the use of gillnets and baited bamboo traps to target spiny lobsters (*Panulirus argus* and *P. laevicauda*) (Paiva et al., 1971). No regulation of fishing effort, combined with recruitment failures due to degradation of nursery areas and over fishing, has meant that most stocks are currently exploited well beyond sustainable levels (Dias Neto and Dornelles, 1996). A steady decline in catches over the past 20 years has resulted in serious social and economic conditions for many fishing communities (Dias Neto and Dornelles, 1996).

In an attempt to improve local conditions, during the early 1980's some operators began to investigate alternative fishing methods and, in particular, pelagic longlines to target stocks of highly migratory oceanic groups of species such as tunas (Scombridae), sharks (Carcharhinidae), and billfishes (Istiophoridae and Xiphiidae). A main contributing factor toward investment in this method was the result of earlier exploratory fishing by leased Japanese longliners operating (from the mid 1950's to 1964) throughout the equatorial Atlantic Ocean. Several large (18 m) artisanal vessels from Natal were modified to include Japanese-style mutifilament longlines (details provided by Suzuki et al., 1977; Hazin et al., 1998) and in 1983 began fishing for tuna (mostly yellowfin tuna, *Thunnus albacares*). By 1996, this fleet had expanded to 10 vessels and although there were several shifts in effort on target species during this period (mainly market- oriented and owing to the discovery of new fishing grounds and stocks), few technological advancements in the types of gears used meant that total catch per unit of effort (CPUE = number of fish caught/100 hooks/day) remained fairly stable at about 2.4 (Hazin et al., 1994b, 1998).

While these catches appear quite low, they are comparable to many other pelagic longline fisheries throughout the world (Kawaguchi, 1974; Sakagawa et al., 1987; Uozumi, 1996) and are indicative of the static nature of the fishing gear and low density and foraging behavior of target species. The effectiveness of pelagic longlines is determined by several interrelated factors including the type, size, and spacing of hooks; vertical distribution in relation to maximum abundance of target species; setting time and direction; and, perhaps most importantly, the stimuli associated with bait (Bjordal, 1989; Løkkeborg and Bjordal, 1992; Løkkeborg and Pina, 1997). The integration of these factors in the pelagic longline fishery off northeastern Brazil means that to provide profitable catches, vessels typically have been required to set at least 1,200 hooks over 35 km of mainline. The logistics of manually operating such gear effectively have limited the size of vessels to a minimum of 18 m, precluding adoption of this fishing method by smaller and more common-sized artisanal vessels of between 8 and 12 m.

The authors are with the Universidade Federal Rural de Pernambuco-UFRPE, Departamento de Pesca, Laboratório de Oceanografia Pesqueira, Av. Dom Manuel de Medeiros, s/n, Dois Irmãos, Recife-PE, Brazil, CEP: 52.171-900. e-mail: fhvhazin@truenet.com.br

ABSTRACT—The catches of three longliners, including two recently converted small artisanal vessels and one large leased foreign longliner, were compared to provide some indication of the feasibility of transferring new longline technology to small vessels in the northeastern Brazilian pelagic longline fishery. Comparisons of catches between the two recently converted vessels operating across the same spatial and temporal scales showed no significant differences for the main target species, providing evidence to suggest that adoption of the technology was rapid and straightforward. A comparison of relative catch rates between one of the recently converted small longliners and the leased longliner across the same temporal scale, but in different areas, showed that while there were significant differences detected for some species, contributing to a significant reduction in total CPUE, the relative abundance of commercially important species within the operational range of the smaller vessels was sufficient for economically viable catches. The results showed that the net financial profit from the artisanal longliner was almost 10 times greater than that derived from existing fishing methods. The inclusion of some artisanal vessels in this fishery may help address the social and economic problems currently faced by fishing communities in northeastern Brazil.

A lack of local vessels of suitable size led to the leasing of several large (>24 m) foreign longliners in 1996. These vessels were equipped with recent advancements in pelagic longline design, including monofilament mainlines and chemical light sticks located anterior to the hooks and designed to increase fish attraction to the baits. Operating in similar areas as local boats, the leased vessels significantly increased catches of most species and particularly swordfish, *Xiphias gladius*, resulting in the rapid adoption of monofilament mainlines and light sticks by established local operators (Hazin et al., 1998).

The effectiveness of this relatively new configuration of longline provides some justification for a significant reduction in numbers of hooks used by existing vessels. More importantly, reductions in the size of gear required to provide profitable catch rates may facilitate a transfer of effort away from larger vessels to those smaller vessels (<12 m) more commonly used by fishing communities throughout northeastern Brazil, thereby alleviating some of the pressure on stocks of commercially important coastal species. Our aims in the present paper are to provide a preliminary analysis of the potential for such a transfer of effort, by comparing 1) relative catch rates of two recently converted small artisanal vessels (to provide some indication of the ease and practicality of adopting pelagic longlines), 2) catches of one of these small artisanal vessels with a large leased longliner across their respective areas of operation (to quantify relative abundance, distribution, and catch rates of target species), and 3) financial return between an artisanal and leased vessel.

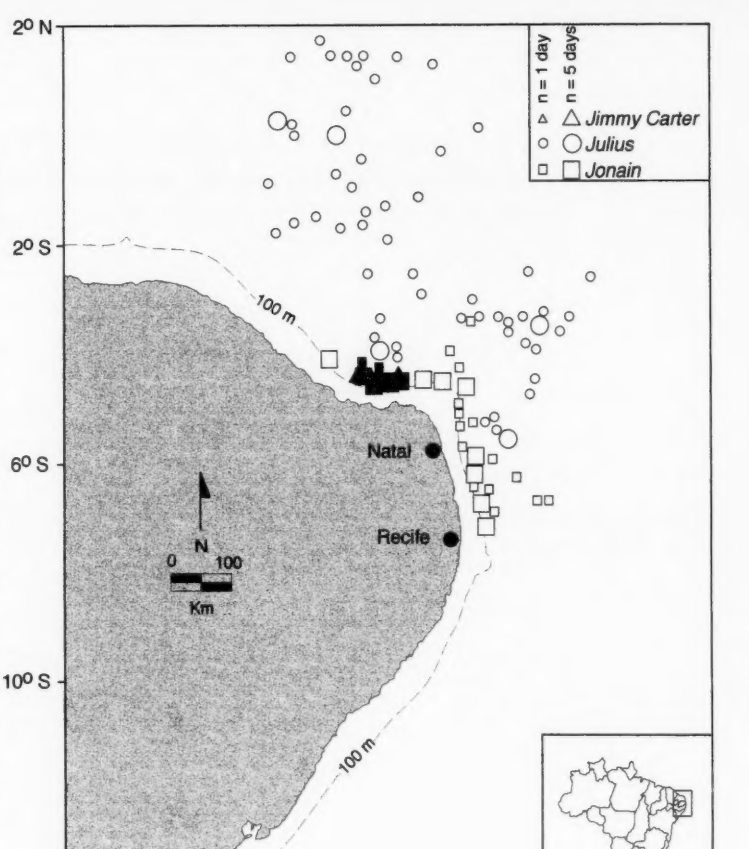

Figure 1.—Location of daily sets of longlines for each vessel during the period examined. The filled squares and triangles represent daily sets of longlines used for the analysis of catches between the *Jonain* and *Jimmy Carter*.

Materials and Methods

This study was done using data collected from two small artisanal longliners (*Jimmy Carter* and *Jonain*, each 12 m in length) and 1 leased American longliner (*Julius*, 24 m in length) operating off the northeast coast of Brazil (Fig. 1) from August 1997 to April 1998. The smaller vessels were almost identical and typical of the artisanal fleet, constructed of wood and powered by small 4-cylinder engines. Their maximum fish storage capacity was 3,000 kg (including ice), and with a crew of 6 they were limited to a maximum of 7 days at sea per trip and an operational range up to 100 km from land. In contrast, the leased vessel was constructed of aluminum, had sufficient space for 40,000 kg of fish, a crew of 8, and autonomy for up to 40 days at sea.

Fishing Gear and Data Collected

The configurations of the longlines used (Fig. 2) were similar across all vessels, with the exception of the length of the mainline and the number of hooks: the *Jonain* and *Jimmy Carter* both used 12 km mainlines with a mean daily number of hooks (± SE) of 289.73 ± 3.22 and 300 ± 0, respectively, while the *Julius* used a 40 km mainline with 1,158.8 ± 21.7 hooks. Each longline consisted of a polyamide (PA) monofilament mainline with a diameter of 4 mm (Fig. 2A).

Secondary lines (PA monofilament 1.8 mm diameter and 15 m in length) were attached with shark clips to the main line at distances of about 35 m (Fig. 2A, B). Styrofoam buoys (about 15 kg buoyancy) each attached to a 20 m line (PA monofilament 1.8 mm diameter) were clipped to the mainline after

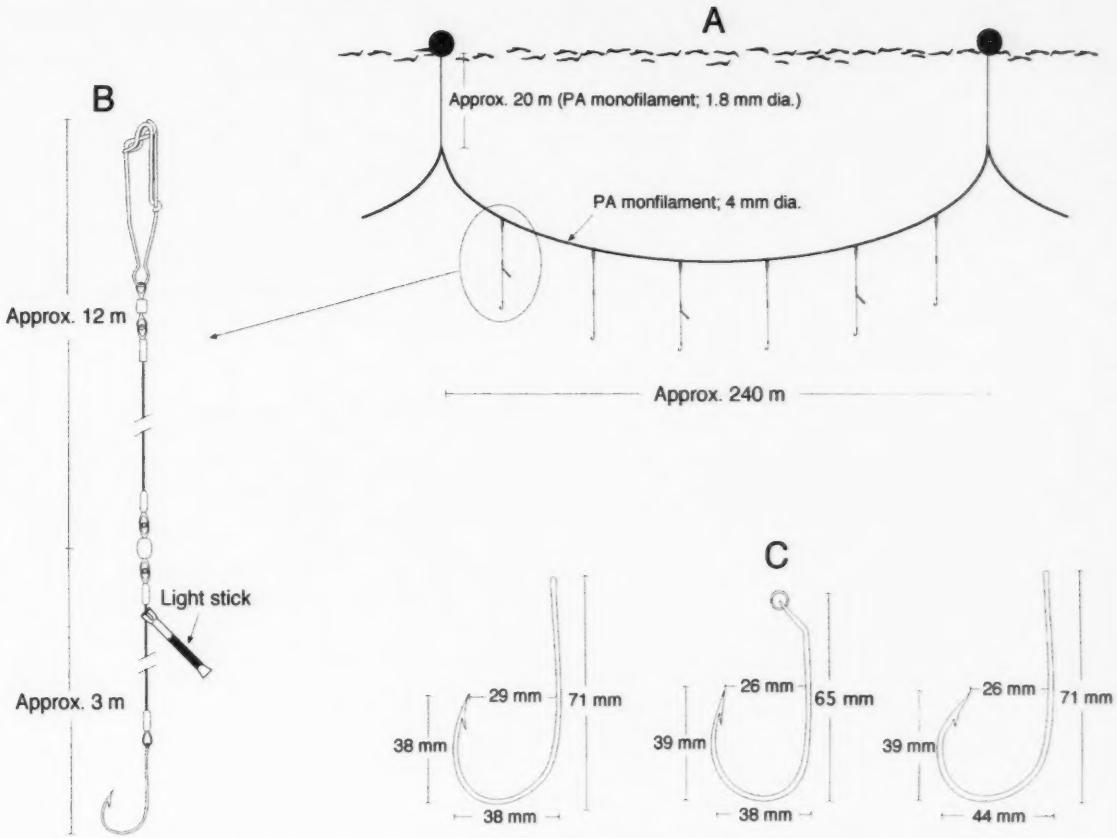

Figure 2.—Diagrammatic representation of A) configuration of pelagic longlines, B) secondary lines, and C) hooks used by all vessels.

every sixth secondary line (Fig. 2A). While the type of hooks used varied among 3 different brands (depending on local availability) their relative sizes remained similar throughout the period examined (Fig. 2C). Hooks were baited with similar-sized (about 140 g) squid, *Illex argentinus*. Light sticks were attached about 3 m above every second hook (Fig. 2B). All longlines were set at between 1600 and 1700 h and retrieved the following morning between 0500 and 0600 h.

Over the period examined (9 months) the number of days fished by each vessel was: 20 (4 trips) for *Jimmy Carter*, 73 (15 trips) for *Jonain*, and 75 (9 trips) for *Julius*. Data were collected from logsheets that vessel operators were lawfully required to complete for each set of the longlines and included location of the longline set, time of setting and retrieval, number of hooks set and configuration (number between buoys), type of bait, and the number of species caught. To provide some verification of catch rates, at the end of each trip the total number of fish unloaded from each vessel was checked against the total numbers derived from the daily logsheets. It was not possible to obtain individual weights of fish caught on each day; only the dressed weights were tabulated after the catch was unloaded from each trip. Further, while individual swordfish were weighed separately, all other species were collectively weighed according to groups (i.e. tunas, billfishes, sharks, and miscellaneous fishes). Sharks and swordfish were weighed without heads or stomachs, other billfishes had their bills removed while áll other species were weighed with heads but not stomachs.

Comparison of Two Artisanal Longliners

To investigate relative fishing performance of the two artisanal vessels and so provide some comparative information on the ability of operators to adopt and effectively use longlines, four replicate daily sets of the longlines were randomly selected from three of the earliest trips made by each vessel over the same spatial (Fig. 1) and temporal scales (between 28 Dec 1997 and 2 Mar 1998). Because the number of hooks set on each day were not constant between the two vessels (see

above) numbers of fish caught were standardized to catch per unit of effort (CPUE), defined as the number of fish/100 hooks/day. To show that there were no significant differences in soak time (defined as the time elapsed between start of setting and start of hauling) between the various daily sets and trips, these were analyzed using Cochran's test for homogeneity of variances and the appropriate two-factor analysis of variance (soak time was nonsignificant at $P < 0.01$). Daily CPUE values for variables that had sufficient data were then tested for heteroscedasticity, transformed if necessary, and analyzed in the appropriate balanced two-factor analysis of variance.

Comparison of Artisanal and Leased Longliners

To examine the relative economic profitability of artisanal and leased vessels, we calculated the cost of various consumable items (using local prices and based on interviews with vessel owners), including bait, ice, light sticks, fuel, equipment losses, and food pooled across all days fished during the sampled period (73 and 75 days for each vessel, respectively). The total numbers, weights, gross return (calculated using local average market prices for each of the species caught) and net return (derived by subtracting expenditure) were then presented for each vessel.

To provide some comparative information on the relative abundance and distribution of target species and fishing performance of the artisanal and leased longliners in their respective areas (across the same temporal scale), data for variables that had sufficient numbers (occurring in at least 12 replicate daily sets) were first standardized to CPUE (as per above). Because individual fishing trips were not standard across vessels (due to differences in distances traveled, vessel size, and autonomy), they were excluded from analyses and data were pooled across all trips. Equality of soak time was determined using a two-sample unpaired *t*-test (nonsignificant at $P < 0.01$). Similar analyses were then performed on CPUE data for the various species captured.

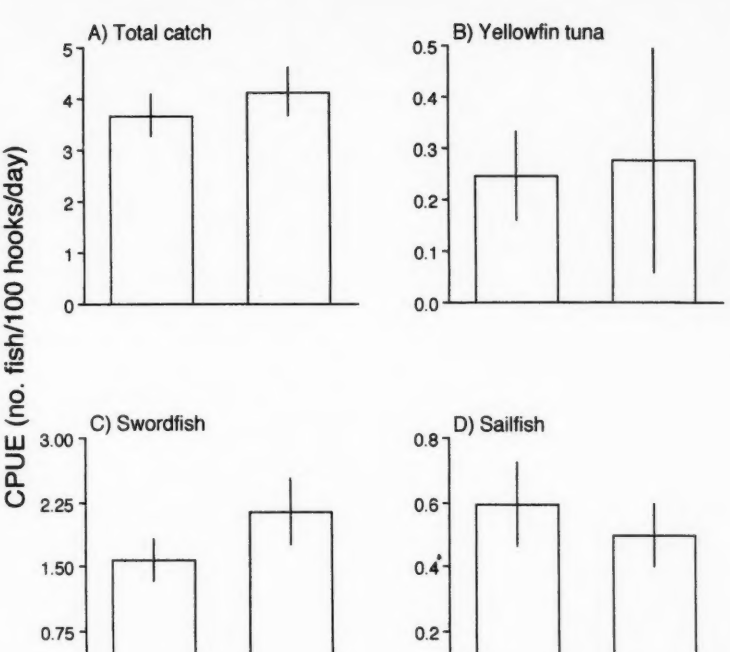

Figure 3.—Differences in arithmetic mean daily CPUE (± SE) of A) total catch, B) yellowfin tuna, C) swordfish, and D) sailfish by the *Jimmy Carter* and *Jonain* across the same spatial and temporal scales.

Table 1.—Summaries of F ratios from analysis of variance to determine effects on CPUE of species due to different longliners (*Jimmy Carter* and *Jonain*) and on different fishing trips. The transforms used to stabilize variances (if required) are also listed.

Source of Variation	df	Total	Yellowfin tuna Sqrt(×)	Swordfish	Sailfish
Longliners	1	0.49	0.40	1.80	1.80
Trips	2	12.53	0.87	0.06	1.14
Interaction	2	0.09	1.41	3.41	1.37
Residual	18				

Results

Comparison of Two Artisanal Longliners

ANOVA comparing CPUE of species between the *Jonain* and *Jimmy Carter* across the same spatial and temporal scales detected no significant effects due to vessels and trips nor any interactions (Table 1). Total CPUE was between 3.8 and 4.1, while the CPUE of individual species ranged from 0.25 (yellowfin tuna) to 2.2 (swordfish) (Fig. 3).

Table 2.—Estimated total costs of consumable items for the *Julius* and *Jonain* over the period examined.

Item	*Julius* Quantity	*Julius* Cost (R$)	*Jonain* Quantity	*Jonain* Cost (R$)
Bait	13,817 (kg)	16,581	3,250 (kg)	3,900
Ice	360,000 (kg)	18,000	45,000 (kg)	2,250
Lightsticks	43,455	36,937	10,575	8,989
Fuel	74,200 (l)	25,970	9,800 (l)	3,430
Lost hooks/ lines		3,178		639
Food		1,802		1,303
Total		102,468		20,511

Comparison of Artisanal and Leased Longliners

Total estimated costs of consumable items and catches and return at point of first sale (pooled across all trips for each vessel) are provided in Tables 2 and 3, respectively. The *Julius* used 86,910 hooks to catch 4,507 fish (114,887 kg) worth R$288,184[1] (net profit of R$185,716 or R$2,476.21 per day fished), while the *Jonain* set 21,150 hooks and caught 792 individual fish (27,547 kg) valued at R$70,565 (net profit of R$50,054 or R$685.67 per day fished) (Table 3).

Compositions of catches by the two vessels in their respective fishing areas were similar among the various groups of species and comprised tunas (>24%), billfishes (>52%), sharks (>14%), and other miscellaneous species of fish (>2%) (Fig. 4). In terms of individual species, swordfish were most dominant, accounting for over 44% of total catch from the *Julius* and greater than 50% from the *Jonain* (Fig. 3B). The only species not represented in catches from both vessels was bigeye thresher, *Alopias superciliosus* (caught only by the *Jonain*) (Fig. 4C).

Two-sample unpaired *t*-tests comparing CPUE between vessels showed that the *Julius* had a significantly greater total catch (5.2) than the *Jonain* (3.8) (Fig. 5A, Table 4) and also increases in albacore, *Thunnus alalunga*; white marlin, *Tetrapturus albidus*; blue marlin, *Markaira nigricans*; blue shark, *Prionace glauca*; and silky shark, *Carcharhinus falciformes* (Fig. 5, Table 4). There were no differences detected between vessels for the catches of swordfish, yellowfin tuna, and bigeye tuna, *Thunnus obesus*; sailfish, *Istiophorus albicans*; other sharks combined, dorado, *Coryphaena hippurus*; and wahoo, *Acanthocybium solandri* (Fig. 5, Table 4).

Table 3.—Total numbers of fish captured, weights of groups of species, and the approximate return at point of first sale for the *Julius* (86,910 hooks) and *Jonain* (21,150 hooks) over the period examined.

	Julius			*Jonain*		
Species	No.	Wt (kg)	R$	No.	Wt (kg)	R$
Tunas						
Yellowfin tuna	383			69		
Albacore	208			16		
Bigeye tuna	585			105		
Subtotal	1,176	31,411	89,521	190	7,395	21,080
Billfishes						
Swordfish	1,922	56,299	159,889	406	15,202	43,174
Sailfish	178					
White marlin	184					
Blue marlin	62					
Subtotal	2,346	65,603	173,839	457	16,539	45,212
Sharks						
Blue shark	438			27		
Night Shark (*Carcharhinus signatus*)	209			2		
Hammerhead sharks (*Sphyrna* spp.)	16			7		
Silky shark	111			34		
Shortfin mako (*Isurus oxyrhinchus*)	30			2		
Bigeye thresher	0			6		
Other sharks comb.	88			37		
Subtotal	892	16,675	18,342	115	2,842	3,077
Miscellaneous fishes						
Dorado	62			14		
Wahoo	31			11		
Other fishes combined	0			5		
Subtotal	93	1,198	1,881	30	771	1,196
Total	4,507	114,887	288,184	792	27,547	70,565
Net profit			185,716			50,054

Discussion

The data presented here showed that relatively small (e.g. 12 m) artisanal vessels can effectively adopt small-scale, monofilament longlines and achieve commercially viable catch rates. By comparing the CPUE of one of these vessels against that of a large (24 m) leased longliner across the same temporal scale we have provided a preliminary measure of its performance and economic return as well as information on the relative abundance and distribution of main target species within its limited operational range.

The results of the comparison between the two artisanal vessels operating across similar spatial and temporal scales showed no significant differences for total CPUE (3.8 and 4.2) or any individual species (Fig. 3, Table 1). Because both vessels had almost identical configurations of longlines (i.e. length of mainline, type and size of hooks, bait, etc.), any differences between relative catch rates would have been due to be the skills and experiences of the crew in selecting areas to fish and in setting and retrieving the gear successfully. The observed results, therefore, provide some evidence to suggest that although the fishing method was new, fishermen on both vessels were equally able to comprehend the methods required to effectively determine appropriate areas to fish and operate the gear. In support of this, the CPUE of both vessels was more than 1.6 times greater than the average CPUE achieved in previous years by larger vessels (using multifilament longlines) operating throughout the full range of the fishery (Hazin et al., 1994b). Further, it is apparent that the period required to become proficient in operating the gear was minimal, since the crew of the *Jonain* had over 2 months experience, while the *Jimmy Carter's* first trips were included in the analysis.

Table 4.—Summaries of two-tailed unpaired *t*-tests comparing daily CPUE of the *Julius* (leased vessel) and *Jonain* (artisanal vessel) operating during the same period (df = 146) (t-v = unpaired t-value, significant *P* values are in bold).

CPUE	t-v	*P*
Total	3.665	**0.0003**
Yellowfin tuna	0.914	0.362
Albacore	3.063	**0.002**
Bigeye tuna	1.206	0.230
Swordfish	1.158	0.248
Sailfish	–0.128	0.898
White marlin	6.413	**0.0001**
Blue marlin	3.511	**0.0006**
Blue shark	6.804	**0.0001**
Silky shark	3.121	**0.002**
Other sharks comb.	–1.042	0.299
Dorado	–0.079	0.937
Wahoo	–0.748	0.456

[1] R$288,184 = US$146,645; at the exchange rate of R$1.00 = US$0.513 as of 10 Nov 2000.

A possible contributing factor towards similar catches between the two vessels may have been the relative efficiency of this type of longline configuration, independent of operator skill. Previous studies have suggested that monofilament mainlines have many advantages over the traditional multifilament, including 1) less retention of bait odor (effectively directing fish towards the baited hooks), 2) lower visibility, and 3) less drag during the hooking process, increasing the probability that hooks are imbedded in the mouth of fish as well as transferring their movements along the mainline, providing stimulus for fish attraction (Bjordal, 1989; Hoey, 1995; Sainsbury, 1996). Similarly, light sticks may provide a primary visual stimulus for target species or, alternatively, aggregate smaller bait fish which in turn attract larger species to the vicinity of the baited hooks (Sainsbury, 1996).

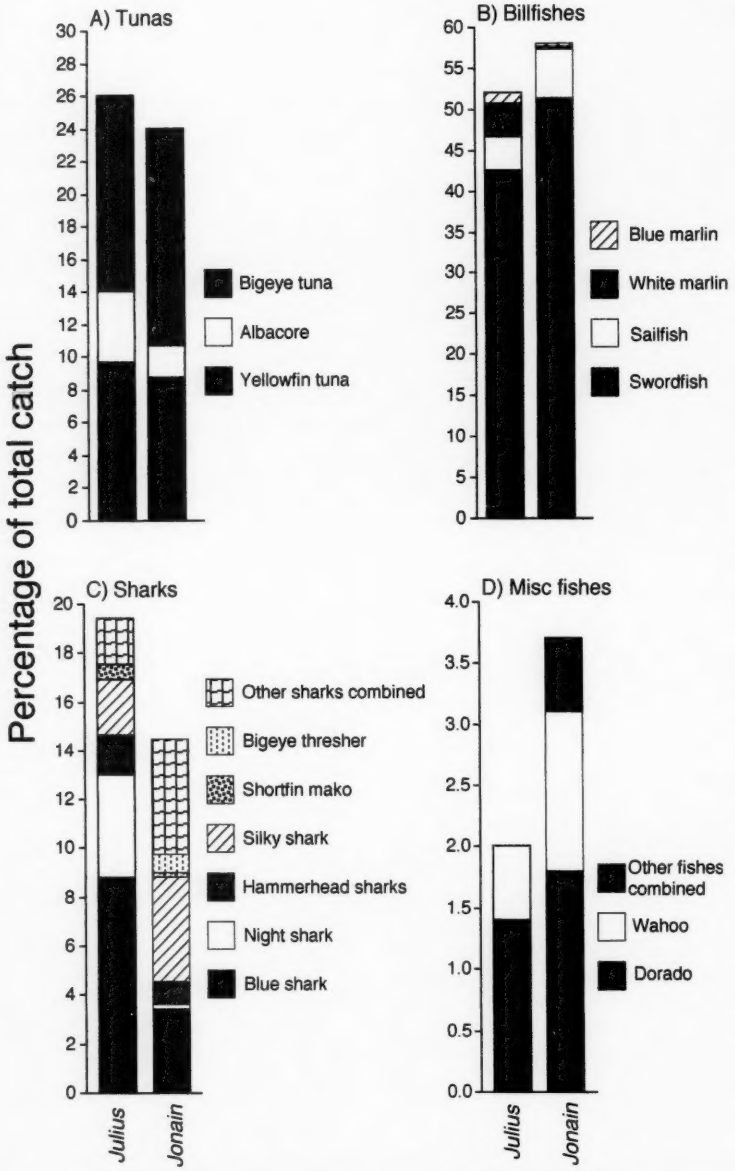

Figure 4.—Percentage composition of A) tunas, B) billfishes, C) sharks, and D) miscellaneous fishes caught by the *Julius* and *Jonain* throughout the total period examined.

Regardless of the specific factors contributing towards the similar fishing performances between the small artisanal vessels, their catch rates during the period examined, combined with the results from the longer-term comparison of catches between the *Julius* and *Jonain* provides some evidence to support involvement in this fishery. Although the total number of fish caught by the *Julius* was much greater than the *Jonain* (Table 3), reflecting absolute differences in numbers of hooks used, the ratios of total catch and financial return to effort were similar. For example, the *Julius* caught 4,507 fish using 86,910 hooks for a return of R$2.14 per hook set while the *Jonain* caught 792 fish with 21,150 hooks and received R$2.36 per hook set. Further, all commercially important species were represented in catches by the Jonain, and although significant differences were detected in the CPUE of some species between vessels (see below), there were no significant differences in the CPUE of main high-value species such as swordfish (accounting for over 50% of total catch from the *Jonain*) and yellowfin tuna and bigeye tuna (Fig. 5E, B, D, Table 4).

Given that the main differences between the *Jonain* and *Julius* were length of mainline and number of hooks set, the significant differences detected in some CPUE's (for mostly lower-valued species) probably reflects species-specific variabilities in relative abundance and distribution between the areas of operation. For example, the *Julius* showed a significant increase in the CPUE of albacore, white marlin, blue marlin, blue shark, and silky shark, contributing to a significant increase in total CPUE (Fig. 5, Table 4). Of these various species,

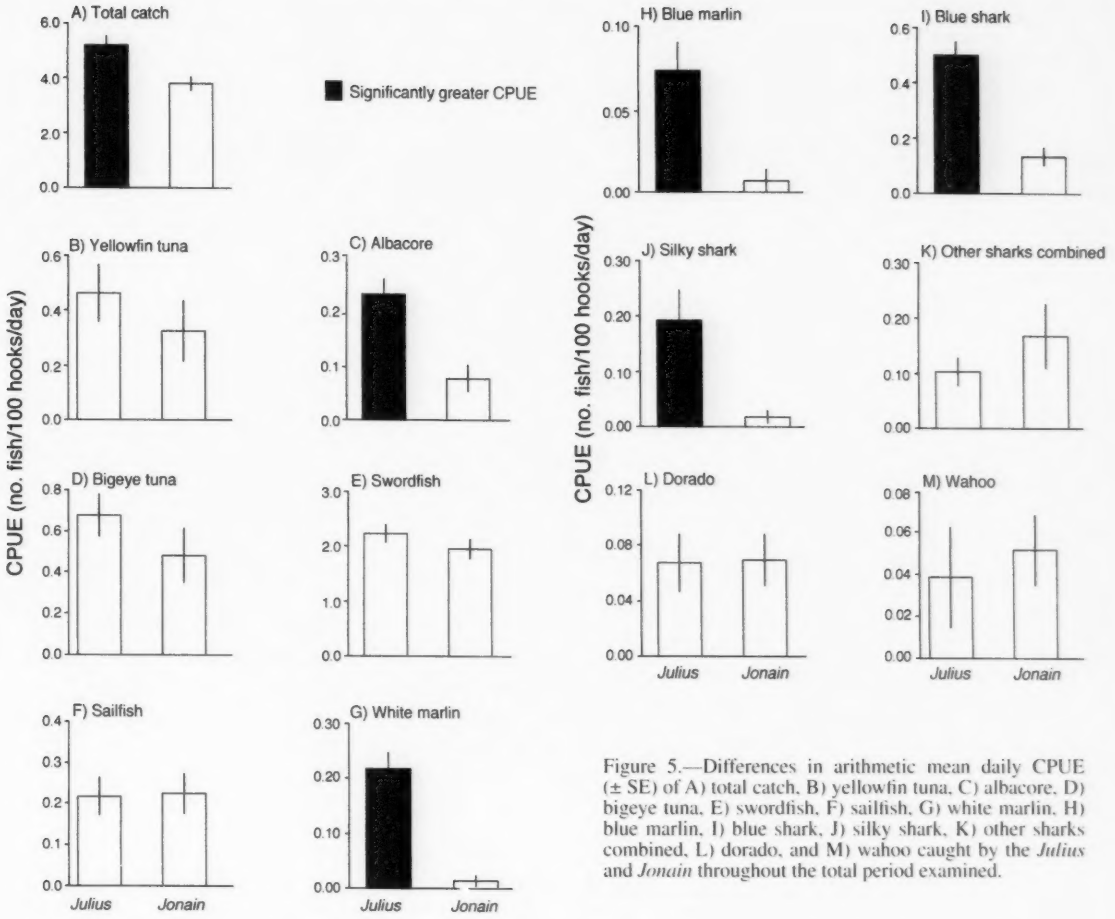

Figure 5.—Differences in arithmetic mean daily CPUE (± SE) of A) total catch, B) yellowfin tuna, C) albacore, D) bigeye tuna, E) swordfish, F) sailfish, G) white marlin, H) blue marlin, I) blue shark, J) silky shark, K) other sharks combined, L) dorado, and M) wahoo caught by the *Julius* and *Jonain* throughout the total period examined.

blue sharks typically are oceanic with an abundance that increases with distance from land (Strassburg, 1958; Hazin et al., 1994a). Similarly, with the exception of sailfish (which showed no significant differences in CPUE between vessels), the species of marlin encountered commonly prefer open ocean and are not usually recorded in shallower areas (i.e. close to the coast) (Nakamura, 1985). The significant increases in CPUE of albacore and silky shark (Fig. 5A, J, Table 4) may be a consequence of fishing in localized areas of maximum abundance, and, in particular, around the many seamounts and shallow banks located well offshore (Travassos et al., 1999 provides details) and outside the operational range of the smaller vessels.

While substantial research is still required to determine the abundance, distribution, and migratory patterns of high-valued target species across the operational range of the smaller vessels (to ascertain levels of acceptable effort), the inclusion of at least some artisanal vessels in this fishery would help address the financial problems faced by fishing communities along the northeast coast of Brazil. For example, Mattos and Hazin (1997) showed that the individual net profit of small artisanal vessels (8–12 m) targeting spiny lobsters over a similar period to that examined in the present study (9 months) was about R$2,520, distributed among three fishermen (i.e. R$840 per fisherman). Excluding the initial costs associated with purchasing the necessary equipment and adapting a vessel for longlining (about R$10,000), the net return from the *Jonain* (R$50,054), represents almost a ten fold increase (i.e. R$8,342 per fisherman). Additional factors supporting a transfer of some effort away from larger vessels (e.g. 18–24 m) might include improved product quality (due to less days spent at sea during each trip), increased business for local suppliers involved in support roles (i.e. shipyards, mechanics, etc.), and perhaps most importantly, a reduction in fishing effort on coastal stocks of traditionally targeted species.

Acknowledgments

This study was funded by the Comissão Interministerial para os Recursos do

Mar (CIRM) through the Programa Nacional de Avaliação do Potencial Sustentável dos Recursos Vivos na Zona Econômica Exclusiva (REVIZEE) and the Conselho Nacional de Ensino e Pesquisa (CNPq). Thanks are extended to the fishing company "Norte Pesca" for their assistance in compiling the catch data and Alceu Alves Couto and João Augusto de Matos Wanderley for technical assistance.

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Historical Exploitation of the California Sea Lion, *Zalophus californianus*, in Mexico

ALFREDO ZAVALA-GONZALEZ and ERIC MELLINK

Introduction

California sea lions, *Zalophus californianus*, have been exploited for centuries along the Pacific coast of the United States and northern Mexico, originally for subsistence and later for commercial purposes. Such use has been revised for California (Cass, 1985), but not for Mexico. This paper reviews the history of California sea lion exploitation in Mexico, based on all published and archival sources available to us. Some of these sources have become unavailable or have been lost since we reviewed them, several years ago.

Sea lion hunting in Mexico can be placed into four historical periods as defined by some of the nation's political events: Prehispanic (to 1533), Colonial (1534–1821), Independent (1822–1911), and Postrevolutionary (after 1911). The dates of these periods are somewhat arbitrary, but give a general framework in which actions and policies can be understood. We ended the prehispanic period symbolicaly in 1533, when Bahía de La Paz was discovered and the Spanish stepped for the first time on the Peninsula de Baja California. The year 1821 marked the ending of the Independence War, and 1911 marked the step-down of Porfirio Díaz as long-time President of México.

The authors are with the Dirección Regional Baja California, Zona de Protección de Flora y Fauna "Islas del Golfo de California," Calle del Puerto #375, altos 25, Fraccionamiento Playa Ensenada, 22800 Ensenada, B.C., México, and the Departamento de Ecología, Centro de Investigación Científica y Educación Superior de Ensenada, Apartado Postal 2732, Ensenada, Baja California, México. U.S. mailing address (for EM) is CICESE, P.O. Box 434844, San Diego, CA 92143. Views or opinions expressed or implied are those of the authors and do not represent the position of the National Marine Fisheries Service.

ABSTRACT—The exploitation of California sea lions, Zalophus californianus, *in Mexican waters can be divided into four periods as defined by political characteristics of the country: Prehispanic, Colonial, Independent, and Postrevolutionary. During the first period (pre 1533), Native Americans took sea lions at low levels. During the second (1534–1821) and the third (1822–1911) periods, most exploitation was by foreigners and was incidental to other marine mammal harvests. During the Postrevolutionary period (after 1911), sea lions were exploited by Mexican and U.S. citizens for several commercial uses. Exploitation officially ended in 1982, although some small-scale poaching still occurs.*

Prehispanic Mexico

Prehispanic maritime tribes used California sea lions for meat, shelter, clothing, and the manufacture of tools (Aschmann, 1959). At least in northwestern Baja California, on the Pacific coast, sea lions were extensively used 1–2 millenia before European contact (Hubbs and Roden, 1964). Native inhabitants seem to have trekked periodically to the shores of Laguna Ojo de Liebre (or Scammons Lagoon) to feast upon a number of resources, including sea lions (Henderson, 1972). We found no further records of prehistoric sea lion use in Mexico, but at least two Indian groups, studied after European contact, can be used as surrogates for the precontact exploitation, as their technology had not been modified by the time their hunts were recorded.

The Concaac (or Seri), a seafaring tribe of central Sonora, hunted sea lions from Isla Tiburón to Isla Ángel de la Guarda, and perhaps other islands, in the Sea of Cortés (or Gulf of California) (McGee, 1898) (Figure 1). They killed them by hitting them on the head and nose with rocks (Felger and Moser, 1985). The Concaac used sea lions (McGee also used the term "seal," although no populations of true seals are resident in the Sea of Cortés, and northern elephant seals, *Mirounga angustirostris*, are only occasionaly encountered) for food, and they probably used the teeth to make harpoons to hunt sea turtles (McGee, 1898; Felger and Moser, 1985). Skins were used to make footwear and groundcloths and for protection against rain (Felger and Moser, 1985). McGee (1898) reported finding pieces of skin and bones of "seal," and a basket whose bottom had been covered with "seal" skin at one ranchería (a small congregation of huts) on Isla Tiburón.

In 1910, Lumholtz (1990) recorded Híac ed O'odham (or Sand Papago) use of sea lions at current-day Puerto Peñasco. The sea lions were killed by hitting them on the nose with rocks, and their skins were used to make sandals and straps.

Colonial Mexico

Spanish involvement with the Pacific Ocean resources along the Californias was basically focused on the extraction of pearls and the use of sea otters for their skins (Mosk, 1931; Ogden, 1932; Gerhard, 1956). During the pursuit of these species, sea lions and other marine mammals were given little attention, if at all.

Sea otters were heavily hunted in the North Pacific as well, and when the returns from these hunts began to

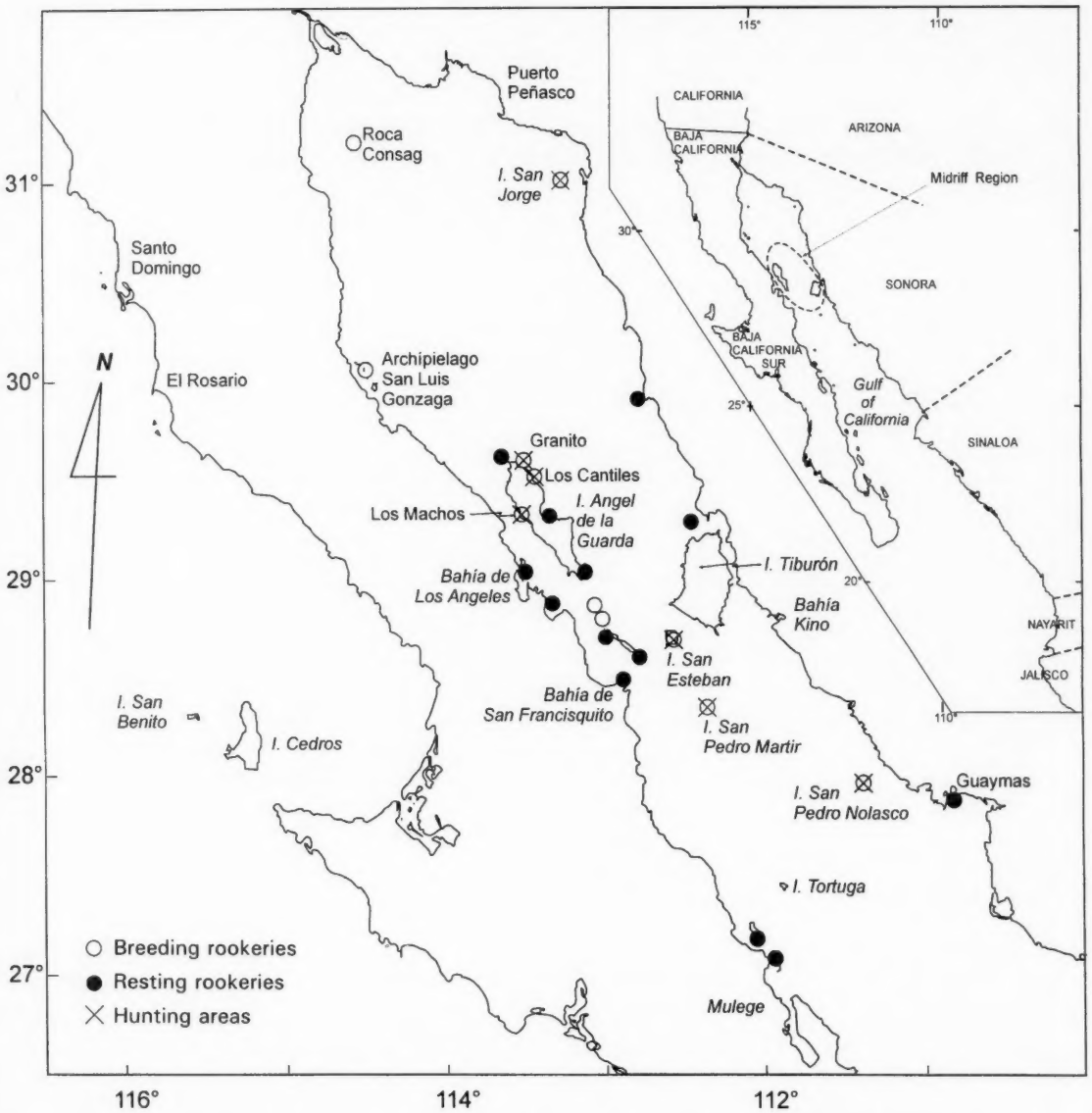

Figure 1.—Sea lion rookeries and commercial hunting sites in the central-northern part of the Gulf of California, Mex.

dwindle, a Russian-American coalition (1803–1812) and independent Russian hunters (1809–1823) heavily exploited southern sea otters, *Enhydra lutris*, in addition to northern and Guadalupe fur seals, *Callorhinus ursinus* and *Arctocephalus townsendi*, respectively, along the Pacific coast of both Upper and the Lower California. Although not the focus of this exploitation, some California sea lions were also taken. This early 19th century period is best described by Ogden (1933), from which we obtained the following extracts.

In 1804, 3 months were enough for the crew of the vessel *O'Cain* to produce 1,100 skins, probably mostly from sea otters, in addition to 700 that captain O'Cain, the master, purchased from Spanish officials and missionaries. Sea otter hunting at this time caused such a population depletion between El Rosario and Santo Domingo, that governor José Arrillaga was prompted to report it to the Viceroy. The number of California sea lions taken during these hunts was not recorded.

In 1806, two Russian-Boston ships hunted along the Pacific shore of Baja California. Expert Aleut hunting gangs were stationed for long periods on different islands. From June to August of that year, one of the ships had taken sea otter and [Guadalupe fur] "seal" skins worth $60,000 in the Canton market. In following years up to 1812, this hunting effort increased, still focused on sea otters and fur seals, but California sea lions were also taken for their skins.

Sea lions have been particularly useful for various commodities. For example, when Fort Ross, on the northern California coast, was a Russian camp, sea lions at the nearby Farallon Islands were a steady source of meat and other products (Ogden, 1933). However, being a "maintenance activity," sea lion hunts were conducted without records of any kind. In this sense, it is particularly relevant that the hunting gangs employed in Mexico were of Aleut origin, as sea lions were a fundamental item in their culture. Sea lions supplied them with meat, blubber, oil, intestines, stomach, and skins for their bidarkas (Scammon, 1874). It is unreasonable to believe that they did not kill any sea lions while stationed on Baja California islands. However, they probably did not engage in the type of sea lion drives used to on the Aleutian Islands as reported by Scammon (1874).

The Russian-Boston hunters hunted illegally, perhaps most of the time. They sometimes blatantly disobeyed Spanish officers, backed by their firearms, and even captured three Spanish officers in Ensenada; other times they avoided them (Ogden, 1933). On 16 April 1811 the Spanish government issued a decree allowing the free take of sea lions, whales, and sea otters in all its New World domains (Sierra and Sierra, 1977), a decree that seemed to have had little effect on the commercial exploitation of sea lions.

Independent Mexico

One early policy of the young Republic of Mexico, the nationalization of commerce, included the appropriation of fishery resources in ways beneficial to coastal communities in 1829 (Sierra and Sierra, 1977). Under this nationalistic scheme, the Russian sea otter hunters were forced to seek an arrangement with Mexico. Some arrangements were made, but the resulting hunts were mostly restricted to the north of San Diego (Ogden, 1933). Only in one instance, in 1828, was the *Baikal*, a ship bound for San Quintín to load salt, allowed to carry two canoes to hunt for sea otters, of which they took 63 between San Diego and San Quintín (Ogden, 1933). It is unknown whether sea lions were hunted on this trip.

On the other hand, by the end of the Spanish rule of Mexico, foreign seamen had begun to explore the west coast of Baja California for sea mammals, including sea lions (Henderson, 1972). Although these whalers focused mostly on the gray whale, *Eschrichtius robustus*, they also took sea elephants and "seals" (apparently sea lion) for their oil (Henderson, 1972).

In the Sea of Cortés, sea lion hunts were unrestricted during the early days of independence. To regulate and terminate the "excesses of the seal hunters," President Ignacio Comonfort granted "exclusive privileges to fish the seal or sea calf[1] along the coasts and islands of the Gulf of California" for an 8-year period to Manuel Mújica, on 6 June 1856. Mújica was to pay the government 80 cents per gallon of oil (Lluch-Belda, 1969). Two years later (30 September 1858), Luis Rivas Góngora was given a 10-year permit to take sea lions and whales in the Sea of Cortés (Sierra and Sierra, 1977).

During the 1860's, the government of Benito Juárez decreed that the hunting of sea lions and whales was to be done according to arrangements with formal obligations. Later, in 1872 new rules allowed for more intensive harvests (Sierra and Sierra, 1977). At the same time there was a deep interest in the development of Baja California. These two factors could explain the apparent shift during this period to an industrialized hunt of sea lions (LeBoeuf et al., 1983). In this context a nonexclusive concession allowed a company to exploit several marine resources, including sea lions, from Altata, west of Culiacán, to the mouth of the Colorado River (Sierra and Sierra, 1977).

The oil of the California sea lion is of low quality and was used in the mid 19th century mainly by tanners to process leather (Cronise, 1868). Anecdotal evidence indicates that the period from 1860 to 1888 brought intensive sea lion harvests, especially for oil extraction (Banfield, 1974; Ronald et al., 1982). Later, trade in hides (for glue and low quality leather) and trimmings (the genitalia, lips with whiskers attached, and gall bladders of bulls) developed (Rowley, 1929; Banfield, 1974). Pup skins were of low quality and of little commercial interest, although they were commercialized to some extent in California (Cronise, 1868; Rowley, 1929).

Adult sea lions were hunted along the Pacific coasts of both California and Baja California, and Scammon (1872, 1874) felt that thousands of sea lions were taken. However, there were no means to obtain accurate accounts on the number of sea lions and other marine mammals killed along the Pacific coast (Taylor, 1869). Browne (1869) considered that these hunts had not attracted as much attention as they deserved, as "myriads of seals and sea lions line the shores and fall an easy prey to the hunter." His statement, and also those of Taylor (1869), apparently referred to only the Pacific coast of Baja California.

While sea lions were intensively hunted along the Pacific coast, the activity was apparently much less intense in the Sea of Cortés (LeBoeuf et al., 1983). During the late 1880's sea lions were hunted for their skin and oil on islands in the Midriff Region of the Sea of Cortés, especially in northern Ángel de la Guarda and San Pedro Mártir (Bahre, 1983). In 1884, fishermen from Mulegé killed 287 sea lions, and in 1905 sea lions were hunted from small fishing skiffs near San Pedro Mártir, Ángel de la Guarda, and San Lorenzo (Nelson, 1921). Such hunts were sporadic and disorganized, and Nelson (1921) considered that the numbers of sea lions were too small to warrant systematic exploitation.

[1] A rather uncommon denomination for the sea lion.

Sometimes sea lions were killed for immediate use. For example, during the late 19th century, eggers (collectors of seabird eggs) on the Farrallon Islands killed sea lions to supply oil for their lamps (Nordhoff, 1875). Egging was widespread in the Sea of Cortés in the late 19th century, and it is likely that sea lions were incidentally killed there. Explorers in the Sea of Cortés also killed sea lions on occasion to obtain oil for their lamps, as noted by Hardy (1829).

At the end of the 19th century, under the rulership of Porfirio Diaz, several concessions to hunt sea lions were granted to Mexican citizens. However, the grantees mostly sought to sell their rights to Americans, Canadians, or Japanese (Bell, 1923). The number of sea lions hunted under such arrangements was not recorded.

Several factors caused the termination of sea lion hunting, or almost so, at the end of this period. The hunt of sea lions brought a steady decline in their numbers along the coast of Alta California into the late 1870's (Bonnot, 1928), and it can be presumed that it caused a similar reduction on the coast of Baja California. As a result, this species was declared protected in California in 1909, an action that caused a halt in the general trade in sea lion products in the United States (Rowley, 1929). However, the Mexican concessions were still in effect. Whether the U.S. protection reduced the hunt in Mexico by restricting the landing of sea lion products in California ports, or increased it since the markets were still available and had a reduced supply, is not known. Nevertheless, declining prices of sea lion oil and hides eventualy made their hunt unprofitable (Bonnot, 1928).

Postrevolutionary Mexico

The Mexican Revolution (1910–21) may have had little affect on sea lion hunting, especially along the Pacific coast, as this war was little felt in Baja California, and the short-termed presidents of the country during it were preoccupied with political matters. Nevertheless, even before the revolution ended Mexico began to reorganize the administration of its natural resources. During the Carranza regime (1917–20), all of the old fishing and marine mammal hunting concessions were cancelled, and various special decrees and regulations were issued. These administrative actions created uncertainty and tended to disorganize the fishing industry (Bell, 1923). However, new entrepreneurs soon appeared (Sierra and Sierra, 1977), and sea lion hunting was again allowed in 1918 (Boletín Oficial de la Secretaría de Agricultura y Fomento, 20 June). During the regime of President Álvaro Obregón (1920–24), fishing, including the hunting of sea lions, was declared free, though subject to a small exploitation fee (Bell, 1923). After the political turmoil of the Revolution settled, the Mexican government slowly imposed a more orderly administration, in the evolution of which the hunt of sea lions went through different stages.

From 1930 to 1940 there was an open hunt (Lluch-Belda, 1969; Zavala-González, 1993). From 1941 to 1955, sea lion hunting was allowed (but a closed season was in effect), from 1956 to 1969 there was a total prohibition, and from 1976 to 1981 hunting was again allowed, with seasonal closures (yearly issues of the Cuadro Oficial de Vedas and dispositions by the Dirección de Pesca e Industrias Conexas of different years). The hunt was prohibited to foreigners in 1976 (Diario Oficial de la Federación, 13 February), and a general prohibition came in effect in 1982 (Secretaría de Pesca, Cuadro Oficial de Vedas).

There are two apparent contradictions in the previous chronology. Hunting calendars for 1941–55 indicated the closed season was from 1 May to 15 July, which seems clearly an error. A 1946 disposition by the Dirección de Pesca e Industrias Conexas and all later calendars indicate this period as the open season. Also, all later hunting was precisely in this period. At that time the information was presented in tables that showed closed and open seasons with shaded and unshaded bars; the meaning of the shading on the calendars from 1941 to 1955 appears to have been reversed (the tables, revised by A. Zavala in 1991, are no longer available). A true contradiction occured in 1971 when the hunting calendar indicated a complete prohibition, but when there was also a disposition by the Dirección de Pesca e Industrias Conexas allowing the hunt of sea lions from 1 May to 15 July. We cannot determine whether this represented an experimental hunt or a political favor superimposed on the prohibition, or an administrative error.

Capture of sea lions for zoos, aquaria, and exhibitions, small but lucrative, developed in California in the 1920's (Banfield, 1974; Mate, 1978; Ronald et al., 1982). This activity often took nursing females, leaving the pups to starve (Bonnot, 1931). Whether any captures of this sort were carried out in Mexican waters is unknown.

Although the industrialization of petroleum products reduced the market for marine mammal oil early in the 20th century, between 1930 and 1945 sea lions were still hunted. Along the Pacific coast of Baja California, some animals were killed for their skins. In 1939 a large number of undressed carcasses were found on Islas San Benitos (Abbott, 1939). Other animals were killed for their trimmings which were sent to the Chinese market, but economic pressures and unsettled political conditions in China reduced this market for Baja California products by the late 1930's (Abbott, 1939).

Also, during the late 1930's sea lion were hunted along the Pacific coast of Baja California by the Dr. W. J. Ross Company, to produce canned dog and cat food (Abbott, 1939), under a concession from the Mexican government. The operation, similar to that of contemporary whalers, made use of three ships, a refrigeration-equipped "killer" ship, a factory ship, and a tender. Fry (1939) speculated that the very high California sea lion counts in California in 1939 could have resulted from individuals moving north to escape those Baja California hunts.

Members of the San Diego Society of Natural History, lead by Clinton G. Abbott, requested that the Mexican government impede such activities. On 8 February 1938, Miguel A. Quevedo, head of Mexico's Forestry, Wildlife and Fisheries Department, reported that

he had given orders not to extend the permit beyond its due date of 10 February 1938 (C. G. Abbott file, SDNHM Archives, box 186). The operations seemed to resume, however, in November 1938 (Abbott, 1939), but ceased some time thereafter.

In addition to this commercial hunt, crew members of recreational U.S. fishing vessels often killed sea lions upon sight, as they were considered competitors (Abbott, 1939). One such killing on Islas Coronado, reported in a letter to the *San Diego Union* (13 July 1939), had dramatic effects on some spectators, but the number of sea lions killed in this context was probably not large.

In 1947 sea lions were still hunted on islands off the Pacific coast of Baja California for their skin and oil, but, according to the Mexican fishermen, the returns were less than the "damage" caused by them (Martínez, 1947). Similarly, commercial hunts for sea lions by U.S. companies along Baja California's Pacific coast were made from 1940 to as late as 1955, but high expenses made the activity unprofitable (Lluch-Belda, 1969). During the late 1950's, some sea lions were reportedly hunted for human consumption, and others were killed apparently by U.S. anglers along the Pacific coast of Baja California (Van Gelder, 1960). There was no apparent use of sea lions during the mid 1960's on the Pacific islands of Baja California (Rice et al., 1965), nor has there been any since then.

In the Sea of Cortés the story was different. During the 1930's, sea lion hunts were officially sanctioned and fluctuated with markets and other factors (Lluch-Belda, 1969). Around the 1930's, the Concaac hunted sea lions using both rocks and rifles (Malkin, 1962). Though the meat was used, the sale of the skins seems to have been the hunt's major purpose, as the Concaac survived in the early 20th century apparently by adopting commercial harvesting of resources, including also that of sharks and other fishes (Spicer, 1978). Interestingly, the ending of sea lion hunting by the Concaac might have resulted from the reduction in the skin market (Malkin 1962). Currently, the Concaac do not hunt sea lions.

In hunts by nonConcaac hunters, oil, meat, skin, and trimmings were used at first, but later only oil was extracted (Lluch-Belda, 1969, 1970). Sea lion meat and skins were not utilized after the 1940's, in part due to the closure of the tannery in Guaymas (Zavala-González, 1993). Altogether, oil was the major commodity obtained from sea lions, while the trimmings were the second most important product. Extraction of sea lion oil peaked in 1951 at 50 metric tons (Table 1), and was obtained at least until 1966, and possibly into the early 1970's. Most of the hunting was performed at Granito, San Pedro Nolasco, San Pedro Mártir, and some beaches of Ángel de la Guarda, notably Los Machos and Los Cantiles.

An important market for shark-liver oil developed after 1937 (Byers, 1940). This led to a shark long-line fishery along the west coast of Mexico, in which sea lions were used as bait. Also, sea lion oil was apparently used to dilute shark-liver oil. From the early 1980's to well into the 1990's, the shark fishery gained momentum in Mexico. Again, sea lions, notably pups, became a common, although illegal, bait (Bahre, 1983, and personal observ.).

In the early and mid 1970's some people, at least from Guaymas, killed sea lions to make jackets for their personal use (J. Mendoza[2]). In addition, even today members of some fishing crews shoot at sea lions, as they consider them a nuisance (Gallo-Reynoso, 1986).

Modern Hunts in the Sea of Cortés

The intent to regulate the harvest of sea lions and other marine mammals led to a formal procedure in the late 1960's in which 1-year permits were granted by the Dirección General de Pesca to kill adult sea lions. The permit holder was required to pay the expenses of a biologist to supervise the cull, comply with the hunting season (from 15 May to 15 July), kill no more than 50% of the adult males in the rookery, use the animals completely, and conduct censuses before and after the hunt. Compliance with the established season was the only rule not violated, and the cull, although restricted to adult males, always exceeded the 50% limit (Lluch-Belda, 1969).

From 10 to 12 sea lions were killed daily at any particular site, because that was the most that could be processed. Between 250 and 600 animals were killed per season, with 400 being a more realistic figure (Aurioles-Gamboa and Zavala-González, 1994). Between 1942 and 1964, the commercial sea lion hunts were almost exclusively made by Sonoran permittees, mostly based at Guaymas.

The hunting party was composed of a hunter, a renderer (the person that boiled the meat to render the fat), and 3 or 4 butchers. The hunt was mostly restricted to adult male sea lions, not only because that was the rule, but also because they produced more oil (Lluch-Belda, 1969).

A camp was established on the beach as close as possible to a rookery. Using stealth to avoid scaring sea gulls or sea lions, the team approached the rookery and shot a male sea lion, with a firearm, from 10–15 m away. As one of the butchers worked on the animal, the other proceeded with the hunt. The dead sea lion was skinned and the layer of subcutaneous fat was removed and taken to the campground, where it was rendered. The rest of the animal and the skin were left on the beach or thrown in the sea (Lluch-Belda, 1969). Although elephant seals are sometimes encountered in the Sea of Cortés, in addition to their being very rare, they were too large for the hunting teams to handle, and it is unlikely that they were ever

Table 1.—Mexican production of sea lion products from the Sea of Cortés.

	Production (kg)					
Product	1936[1]	1942[2]	1943[2]	1951[3]	1952[2]	1953[2]
Oil		16,245	31,674	50,000	15,430	22,049
Meat		149	15,000			
Trimmings		23	25		43	75
Skins	509	76				

[1] Boletín Forestal y de Caza y Pesca.
[2] Anuarios Estadísticos de Actividad Pesquera en Aguas Territoriales Mexicanas.
[3] Lluch-Belda (1969).

[2] Jorge Mendoza, Procudaría Federal de Protección al Ambiente, México, D.F. Personal commun., 1997.

included in the hunt. After a couple of weeks of hunting and rendering fat, the oil and trimmings were taken to port and shipped to their markets.

Concluding Remarks

In 1966 10,366 adult California sea lions were counted in the seven largest breeding rookeries in the Sea of Cortés. In 1991 the tally on the same rookeries was 17,486 (Zavala-González, 1993). This increase occurred despite the fact that some killing of sea lions happened throughout that period (indeed, albeit illegally, some killing has persisted to date).

The increase in numbers of sea lions since 1966 has resulted in increased interactions between them and fishermen. Sea lions are increasingly being entangled in fishing gear (Zavala-González and Mellink, 1997), and fishermen have started to complain about damage to their fishing gear; some also have requested that sea lions be culled to lower their numbers. At the same time there has been an emergence of environmental groups, some of which would clearly oppose any intent of culling the sea lions. Others would probably demand extensive and intensive studies that exceed the current abilities. In addition, some international organizations might also try to press the Mexican government in the direction of their own viewpoints or interests. So, it is forseable that in the near future some conflicts will emerge on the management of California sea lions in Mexico.

Acknowledgments

We thank Carlos Esquivel, Claudia Hernández, and Jaime Luévano for their assistance during the literature search. W. L. Hobart provided important editorial assistance. Our gratitude to all of them.

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Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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